THE GLASS INDUSTRY

VOLUME 21, NUMBER 4, APRIL, 1940

Foreword

Although glass has been known to exist for nearly 50 centuries, the period of greatest advancement in the art of its manufacture is the immediate present. It has been within the past 20 years that a continuous process for making plate glass has been developed; that forming machines have been perfected to such an extent as to have virtually recreated the glass container industry; that plants have become modernized and mechanized. Little more than a decade has elapsed since glass technologists really began to acquire an understanding of the nature of glass and hence have been able to control to some extent its properties.

During the span of these same 20 years, THE GLASS INDUSTRY came into being. What more fitting than that the editors should pause momentarily in their task of recording current problems of glass making and dedicate this their twentieth anniversary number to a review of all that has taken place.

In undertaking this, we have kept in mind the accelerated tempo of the age, which is also so peculiarly a characteristic of glass making. In the morning we learn how to build the largest astronomical reflector and by evening we have worked out the unbelievably complicated problems of the sealed beam headlight. Hardly have we discovered a glass with a refractive index higher than ever was known before, than we are ready to try our hands at reconstructed ware.

So rapidly does this parade of progress move that we who are actors in the drama find ourselves too preoccupied with our individual problems to find time to view the larger spectacle and to appreciate its full significance. Hence, in developing this Review of Progress, we have had to have an eye for this hurried and harassed glassman of 1940. Our March of Time perforce must be a tabloid.

We take this opportunity to express our thanks to all who have labored in the production of this anniversary number. Particularly we have in mind our contributors, whose articles are outstanding (though credit us with the persuasive powers that induced them to undertake the job)! We also pay tribute to the advertisers—and do not let it be forgotten that they, perhaps as much as any glassman, have made important contributions to these 20 years of progress. And finally, we thank our readers. Today our reader audience is probably the largest in the glass industry, and the encouragement that they, our subscribers, have expressed so often and so generously has added inspiration as well as enjoyment to the task of publishing THE GLASS INDUSTRY.

Editor and Publisher

RECENT TRENDS IN GLASS COMPOSITION

By DONALD E. SHARP*

Although the last twenty years have witnessed the commercial development of many new types of glass for special purposes, nevertheless the great bulk of the glass manufactured throughout the world and used for windows and containers is still sand-soda-lime glass, just as it was 2000 years ago, and as it probably always will be. It is not to be inferred that there have been no changes whatsoever in compositions used for window glass or bottle glass in the last two decades, for this would be far from true, but such changes as have been made may well be said to have been minor changes in major ingredients or major changes in minor ingredients. It is the latter that are of greater interest.

Raw Materials

The principal raw materials used to supply the major ingredients, silica, lime, and alkali, are still sand, lime and soda ash. Any other raw materials, whether used to supply the above three ingredients or to add other materials to the composition, may be considered as minor ingredients, even though the effects produced may be of major importance.

A case in point is borax, which, as a minor ingredient, supplies the glass with both sodium oxide and boric oxide, the former being a major ingredient of lime glass, obtained principally from soda ash, and the latter being a minor ingredient imparting quite unusual properties to the glass. Though seldom found in window or plate glass, borax has come into quite common use in container glasses during the last twenty years. Its particular virtue is its fluxing power. Substitution of borax for part of the soda not only lowers the expansion coefficient, but increases chemical durability. Because of its relatively high cost, the quantity of borax employed is not large, the average being enough to yield about 0.7 per cent B_2O_3 in the glass. Borax is not used universally by any means, but the same may be said of many of the minor ingredients such as barium, feldspar, and ammonium sulphate.

The long-accepted use of saltcake as a minor ingredient of the glass batch stimulated the employment of other sulphates. For a time ammonium sulphate was used as a minor addition to the glass batch, its merits having become recognized through the researches of Turner[1] and his co-workers. They found in small scale operations that 10 parts of ammonium sulphate to 1000 parts of sand shortened the melting time, and that ammonium sulphate was more effective generally as an accelerating agent, both in melting and refining than was saltcake.

A more comprehensive test of the effect of ammonium sulphate was described by Vickers[2] who confirmed for commercial scale tank practice the conclusions arrived at on a small scale by Turner and his co-workers.

The interest in ammonium sulphate was short-lived, and before many years was replaced by interest in compounds of barium. Although the degree of this interest quite evidently has varied in proportion to sales activity, nevertheless barium is a not infrequent component of container glass, and may even be encountered occasionally in a window glass. Moreover, although barium has long been an ingredient of glass, several patents have been issued in recent years, based on novelty of form in which it is introduced.

Among the interesting patents, Fisher[3] claims the use of barium sulphate, barium sulphide, barium compounds together with titanium, and barium salts with barium oxide for making crystal glass. Rothe and Brenek[4] describe a process for making barium silicate for use as a glass ingredient. Harth[5] advocates barium aluminate, and Heinz[6] a borosilicate combination with barium. F. C. Flint[7] claims a combination of barium sulphate with a metal halide such as sodium chloride, barium sulphate in combination with a metallic reducing agent such as zinc, and barium sulphate in combination with a carefully calculated quantity of carbon.

Substantial use is or has been made of barium, the quantities involved being of the order of about 0.5 per cent of the glass. In addition to glassmakers' barium sulphate, and to the special mixtures containing barium furnished by some purveyors of glass-making chemicals the use of barium carbonate is not infrequently encountered.

Feldspar had been used for years in substantial percentages as an ingredient of opal and alabaster glass. About twenty-five years ago its use in minor amounts in container glass for improving chemical durability and reducing the tendency toward devitrification, began to attract notice. During the last decade, through determined effort on the part of feldspar producers and enlightened glass manufacturers, the quality and uniformity of the material has been improved so greatly that feldspar may now be considered almost as a standard ingredient of container glass. As the quality was improved, larger percentages have been employed, so that today it is not unusual to encounter glasses containing 2.0 to 3.5 per cent of alumina, derived from feldspar or from some of the other sources of alumina, such as nepheline syenite.

In 1937 the National Feldspar Association issued a booklet[8] which went into some detail on the composition of feldspar, its advantages in glass, calculating batches, compositions employing feldspar, and so forth. The composition of typical feldspars, quoted from the booklet, are given in Table I.

TABLE I

		Potash Spar	Soda Spar	Typical No. 17 Glass Spar
Silica	SiO_2	67.93	68.53	69.0
Alumina	Al_2O_3	18.20	19.59	17.4
Iron Oxide	Fe_2O_3	0.07	0.064	0.08
Calcium Oxide	CaO	0.20	0.71	0.1
Magnesia	MgO	nil	trace	nil
Soda	Na_2O	2.70	9.52	3.0
Potassium Oxide	K_2O	10.50	1.29	10.0
Ignition Loss	....	0.40	0.28	0.4

*Hartford-Empire Company.

In recent years substantial quantities of Nepheline Syenite have come into use as a source of alumina in glass, improved methods of purification having brought the iron content of this material down to a point comparable with good feldspar. Although the economics of these alumina-containing materials other than feldspar have probably not become completely settled, it is safe to say that the materials will continue to find employment in glass.

Table II gives typical analyses of Nepheline Syenite, and "Nepheline," these being two materials which are used in substantial quantities.

TABLE II

	A	B
SiO_2	60.22	54.40
Al_2O_3	23.72	26.61
Fe_2O_3	0.06	0.08
CaO	0.42	1.95
MgO	0.09	....
Na_2O	10.06	12.85
K_2O	5.04	2.97
L.O.I.	0.47	1.50
	100.08	100.36

A. Typical analysis of Grade "A" Lokefield Nepheline Syenite.[9]
B. Typical analysis of No. 275 New England "Nepheline."[10]

One should not be hasty in judging the purity of any of these materials on the basis of the actual percentage of iron carried. The important point, of course, is the total introduced relative to what would have been introduced by the materials for which these newer ones are substituted. Indeed, this reasoning has led to the employment of "Aplite," a lime-containing source of alumina which would at first seem to be unsuitable on account of its iron content and yet which, because of its high alumina content, and the fact that it replaces part of the lime, has been utilized in both container and flat glass. A typical analysis of Aplite is given in Table III.

TABLE III

SiO_2	60.34
Fe_2O_3	0.31
Al_2O_3	23.76
CaO	6.08
Alkali	8.98
L.O.I.	0.53

Typical Analysis of Aplite from Piney River, Va.

The minor ingredients discussed in the foregoing do not constitute the full list of such materials. Arsenic is still a customary ingredient in most container glasses and in many window glasses. Niter is a frequent companion of arsenic, in glasses decolorized by selenium. The use of manganese as a decolorizer is confined almost exclusively to pot glass.

Sheet and Plate Glass

Although the last several years have seen a gradual increase in quality of drawn window glass for flatness, freedom from waves, stones, and so forth, compositions in use today are substantially identical with those employed twenty years ago. The same may be said too of rolled, figured and plate glass. Special compositions have been worked out, of course, where a glass with unusual physical or chemical properties is desirable, but such glass generally is not manufactured in large quantities. Typical ranges of composition for the customary types of glass may be found in Table IV.

TABLE IV

	Sheet drawn Glass	Rolled and Figured Glass	Plate Glass
SiO_2	71.0-73.0%	70.5-72.5%	70.5 - 73.0%
$Fe_2O_3+Al_2O_3$	0.5- 1.5	0.5- 1.5	0.5 - 1.5
CaO	8 -10	11 -14	13 - 14
MgO	1.5- 3.5	0 - 2	0 - 1
Na_2O	14 -16	12 -14	12 - 14

Range of compositions abridged from *Composition of Commercial Glasses* [12].

There are little accurate data in the literature on the compositions of glass made in the last few years. A few are listed in Table V and bear out the contention that there is slight difference in composition today from that of twenty years ago.

TABLE V

	1	1a	2	3	4	4a	5
SiO_2	71.0	71.3	72.1	72.1	72.9	72.	72–73
$Al_2O_3+Fe_2O_3$	1.0	0.7	....	0.3	1.1	1 –1.7	0.5–1.5
CaO	8.5	9.9	11.5	9.9	9.3	11	13–14
MgO	3.5	2.4		3.2	3.6	2.5–3	
Na_2O	14.5–15	14.9	16.3	14.0	12.9	12.5–13	14–15
SO_3	....	0.7	....	0.4	0.4	....	....

1. Fourcault Glass.[13] 1a. Newer Fourcault Glass.[14] 2. Fourcault Glass, American, calculated from batch.[15] 3. Penn Vernon Window Glass.[16] 4. Libbey-Owens, B. Long, Loc. cit. 4a. Libbey-Owens.[17] 5. Plate Glass.[18]

Sheet glasses for special purposes are now manufactured in the U. S. A. and abroad. Among such glasses are those for the transmission of ultraviolet, others for the absorption of ultraviolet, as well as glasses for absorbing infra-red rays, for obtaining daylight effects, and so forth.

Taylor[19] in 1930 patented an ultraviolet transmitting glass in which vein quartz is the source of silica. In the same year, B. Long[20] disclosed a glass containing less than 0.02 per cent ferric iron and from 0.05 per cent to 0.5 per cent manganese dioxide. Gould, Hampton and Martin[21] show a batch for ultraviolet transmitting glass, consisting of silica, 560 parts, borax, 527 parts, and powdered metallic zinc, aluminum, or tin, 8 parts. Hood[22] disclosed zinc-containing glass of low iron, titanium and lead content. He also shows colorless calcium phosphate glass, as well as similar glasses colored by chromium, cobalt, vanadium, uranium and nickel. Another patent covers a composition consisting of 74 per cent SiO_2, 6 per cent B_2O_3, 15 per cent Na_2O, 4 per cent ZnO and 1 per cent Al_2O_3 with iron content of less than 0.01 per cent and melted under oxidizing conditions. Hood also disclosed a method of heat treating ultraviolet transmitting glasses which have become solarized to restore their ultraviolet transmitting properties. Locke[23] in 1932 disclosed a process for making glass that would transmit ultraviolet, in which the batch contains silica, boric oxide, alumina and calcium oxide in the presence of fluorine. Fuwa[24] claims a glass batch containing principally silica, boric oxide and alkali and small percentages of a halogen compound and an alkaline tartrate. He and Suzuki show also a conventional glass composition to which is added 1 to 5 per cent sodium fluoride and 1 to 5 per cent ammonium oxalate. Kaufmann and Bungartz[25] claim the use of barium metaphosphate as a principal ingredient of ultraviolet transmitting glass. Josephus Antonius Maria Smelt[26] of Eindhoven, Netherlands, claims a glass containing 65 per cent SiO_2, 2 per cent B_2O_3, 5.5 per cent Na_2O, 9.5 per cent K_2O, 15 per cent BaO, 3 per cent ZnO, iron in traces and 1 kg. fluoride to 100 kg. of the glass mixture. A transparent phosphate glass was disclosed by Huppert and Wolff[27] in which ammonium

phosphate is added to a typical phosphate composition.

Oil paintings and valuable documents may be preserved from fading or alteration in color caused by light, if special ultraviolet absorbing glass is used as a protective covering. Such glass is also of value in shatterproof glass for automobile windshields, in which discoloration of the intermediate layer used to be a serious problem, and for eye-protecting goggles.

In 1922 Taylor[28] patented a flesh colored glass of high ultraviolet absorption, containing cerium oxide and manganese. Parkinson[29] disclosed a clear, colorless, ultraviolet absorbing glass, containing cerium oxide free from didymium, and a yellow tinted glass colored by cadmium sulphide and sulphur. Frank[30] claimed a glass of high ultraviolet absorption, containing manganese and ferric oxide, while Gelstharp[31] disclosed glass containing cerium and iron, and a glass for windshields containing iron in amounts from 0.2 to 1 per cent.

It is not necessary to employ glass of special composition for the heat-treated glass, about which so much has appeared in the literature in recent years. The special properties of this glass are derived from controlled amounts of strain in the product, produced by chilling the glass under properly controlled conditions.

Similarly, in the case of shatterproof glass, no special composition is necessary in many cases. However, if the inside layer of the "sandwich" is sensitive to the action of ultraviolet, recourse may be had to a composition high enough in iron to absorb the ultraviolet before it reaches the plastic layer, as is pointed out in the foregoing.

Container Glasses

Progress in container glass manufacture in the last few years has been largely of a mechanical nature. Compositions differ slightly from those in use a decade or two ago; for example, in their alkali content, which may be said to be slightly lower on the average than formerly. Alumina is now quite a customary constituent of container glass, and is derived from feldspar, nepheline syenite, nepheline, or aplite. Many container glasses employ special constituents such as boric oxide and barium. Representative compositons of some container glasses are given in Table VI.

TABLE VI

COMPOSITIONS OF CONTAINER GLASSES

	Gob Fed Glasses					Owens Operation	
	6	7	8	9	10	11	12
SiO_2	74.2	71.8	70.4	73.5	73-75	73.5	71.5
R_2O_3	1.3	1.6	3.1	1.2	0.5	0.7	0.8
CaO	4.6	9.6	9.7	5.6	8-10	6.0	6.0
MgO	3.4	0.3	0.3	3.8		4.0	4.3
BaO	....	0.6	0.1	....	....	0.6	0.6
Na_2O+K_2O	15.1	15.7	16.4	n.d.	16-17	15.0	16.6

6. Gob-fed flint bottle (1931).[32] 7. Gob-fed flint bottle (1938).[32] 8. Amber bottle (1938).[32] 9. Milk Bottle (1928).[32] 10. Gob-fed flint bottle.[33] 11. Flint bottle Owens operation (1938).[32] 12. Emerald green bottle Owens operation (1938).[32]

The influence of the liquor trade has been noted in the tendency among manufacturers of such ware to make glass particularly high in alumina and lime, and particularly low in alkali. Such glass melts with more difficulty than the typical container glass of 1920, but it is more chemically resistant and has come into considerable use in the last few years.

In general, the color of container glass may be said to be much better than it was twenty years ago. This is due principally to better selection and purification of raw materials, although the improvement in tank blocks during the last two decades also has played an important role. Moreover, manganese is no longer used in tank glass, selenium now being the universal decolorizer, generally combined with appropriate amounts of arsenic and cobalt.

Tableware

The trend toward color in glass reached its climax about ten years ago when almost all of the colors of the rainbow were employed in the manufacture of plates, goblets, dishes, and other articles of tableware. In recent years colored glass took a sudden drop in popularity, when good taste dictated the use of flint of maximum clarity.

Represented among the shades of glass in the color age were blue, green, pink, yellow, amber, amethyst, smoke and ruby. Alexandrite, a dichroic glass, which had a blue cast in daylight and a decidedly pink character under artificial light, was one of the most unusual of the colored glasses, and derived its color principally from neodymium oxide.

Typical compositions for some of the colored glasses mentioned above, as well as for the high grade crystal which remained after the color popularity waned, are given in Table VII.

TABLE VII

TYPICAL COMPOSITIONS OF COLORED TABLEWARE GLASS

	13	14	15	16	17	18	19
SiO_2	71.0	74.3	74.3	69.7	70.5	71.3	67.2
R_2O_3	0.4	0.5	0.4	0.2	0.7	0.4	....
CaO	7.2	4.3	6.5	4.1	2.7	0.4	0.9
MgO	....	3.1	....	3.0	....	....	....
PbO	3.5	....	....	....	8.4	....	14.8
ZnO	....	....	....	....	....	10.0	....
Na_2O	17.1	17.3	10.8	18.0	15.9	11.7	9.5
K_2O	....	....	7.3	....	....	4.5	7.1
As_2O_3	0.5	0.2	0.3	....	0.5	....	0.5
B_2O_3	....	....	0.4	....	1.3	0.3	....
CuO	0.2	0.03	....	....	....	....	....
U_3O_8	....	0.2	....	....	....	....	....
Cr_2O_3	....	0.03	....	....	....	....	....
TiO_2	....	....	....	2.5	....	....	....
CeO_2	....	....	....	2.5	....	....	....
CdO	....	....	....	....	....	1.4	....

13. Blue glass colored by copper. 14. Green glass colored by uranium, copper and chromium. 15. Pink glass colored by selenium. 16. Yellow from cerium and titanium. 17. Amber made on light lead base and colored by selenium. 18. Red glass colored by cadmium and selenium. 19. Conventional lead crystal for tableware.

An interesting development in ruby glass which is suitable for machine made tableware is described by Dobrovolny, Youel & Klein[34], who in 1939 developed a ruby glass for which the following batch was quoted:

Sand	110
Potassium Carbonate	10
Sodium Carbonate	40
Calcium Oxide	13
Aluminum Oxide	3.5
Cuprous Oxide	0.25
Stannous Oxide	0.32
Sodium Cyanide	1.25

The inventors claim that the mix may be charged into a glass tank and fused in the usual manner, after which the melt is subjected to the usual fining treatment. The glass melt is then worked to obtain a ware having a bright ruby color.

Special Glass

Various types of glass for special or technical use have been developed to a high degree of efficiency during the last two decades. Among these are glasses for absorbing heat, as well as several types of heat resisting glasses, "Daylight" glasses and other glasses for filtering out various portions of the visible spectrum, optical glasses with unusual dispersive properties for a given level of refractivity, X-ray absorbing glass, and special compositions for fibers.

Heat absorbing glasses depend in general on the well-known effect of ferrous iron for absorbing the infra-red end of the spectrum, which first was pointed out by Sir William Crookes[35] in 1914. An early glass composition quoted by Alleman[36] for a glass made by Sherwood, and repeated in various places in the literature, shows the glass to be an ordinary soda-lime glass, colored by iron, nickel, titanium and manganese, and melted under definitely oxidizing conditions, whereby the glass is obtained with a yellowish or amber color. All of the more recent developments in heat absorbing glass, however, follow the principles laid down first by Crookes, that the iron should be in the reduced form in order to obtain the maximum ratio of light transmission to infra-red transmission.

Rising[37] in a heat absorbing glass patent discloses the use of tin and zinc oxides with reducing agents for insuring virtually complete reduction of iron to the ferrous form. W. Linke[38] patented windows of heat absorbing glass. E. Berger[39] of the Jena Glass Works disclosed a composition for a heat absorbing glass in which substantial quantities of phosphoric and boric acids are employed and the absorptive material is ferrous iron. Sharp and Bailey[40] patented a soda-lime glass in which the ferrous iron is stabilized by the presence of antimony, and the use of a metallic reducing agent in combination with a carbonaceous one. Sharp and Horak[41] disclose a heat resisting, heat absorbing glass of low expansion and of high alumina, high lime, and low alkali content. Compositions taken from a number of these patents are shown in Table VIII.

TABLE VIII

HEAT ABSORBING GLASS COMPOSITIONS

	20	21	22	23	24
SiO_2	71.5	71.5	....	70.4	46.5
Na_2O	6.0	15.4	....	14.5	5.4
B_2O_3	8.0	....	4.0	....	....
ZnO	12.0	9.6	1.0	....	4.6
FeO	1.5	1.75	2.5	0.18	1.4
Al_2O_3	1.0	....	10.0	0.9	10.9
SnO	....	1.75	....	....	....
Sb_2O_3	....	....	....	0.9	....
P_2O_5	....	....	70.7	....	....
K_2O	....	....	10.0	....	....
CaO	....	....	....	13.2	18.0
MgO	....	....	4.0	....	13.2
As_2O_3	....	....	0.3	....	....

20. W. H. Rising (U.S.A. Patent 1,737,685 Glass A). 21. W. H. Rising (U.S.A. Patent 1,737,686 Glass B). 22. E. Berger (U.S.A. Patent 1,961,603 Glass E). 23. Calculated Composition, Sharp and Bailey (U.S.A. Patent 2,034,994 Glass No. 2). 24. Sharp and Horak (U.S.A. Patent 2,144,943 Glass 3881E).

The trend of the early developments in laboratory and heat resisting glass was toward obtaining as low an expansion as was consistent with temperature and equipment available for melting and working the product. Composition data on these earlier glasses are available in the literature but a few are reproduced in Table IX for convenient reference.

TABLE IX

	25	26	27	28	29
SiO_2	64.7	73.0	67.3	80.5	75.7
B_2O_3	10.9	3.6	6.2	12.9	6.9
R_2O_3	4.5	1.4	2.7	2.2	5.2
ZnO	10.9	5.6	7.8	....	....
CaO	0.6	0.7	0.8	....	1.3
MgO	0.2	4.3	3.4	....	....
BaO	....	....	....	....	3.6
Na_2O	7.5	10.8	10.9	3.8	6.2
K_2O	0.4	0.3	0.3	0.4	1.2
As_2O_5	0.1	0.02	....	....	....
Sb_2O_3	....	0.6	0.6	....	....

25. Jena Glass.[42] 26. Macbeth-Evans.[42] 27. Non-sol glass.[42] 28. Pyrex brand chemical resistant glass.[43] 29. Laboratory glass 2877 III, Schott u. Gen. Av. of 6 Analyses.[44]

In 1936 the Corning Glass Works[45] announced a new type of Pyrex brand glassware of unusual thermal shock resistance, which they called Top-of-Stove ware. Although no data on its composition were given in the announcement, it was described as a low expansion glass having a coefficient of expansion of about 38½ compared to 32 for Pyrex brand chemical glassware (and to about 90 for ordinary glass). The glass has such a high strain point that heat resistance is obtained beyond that previously available in any commercial glassware.

A more recent development of great interest is the new process attributed to Hood and Nordberg[46] in which a borosilicate glass of special composition is fashioned into ware and by subsequent heat treatment becomes slightly opalescent. The composition and treatment are so chosen that a separated phase may be leached out by appropriate treatment with acids, leaving a transparent article containing a multiplicity of exceedingly minute pores. These pores may be closed by further heat treatment, the article shrinking in size about 20 per cent in the process, leaving an article of almost pure fused silica which is exceedingly resistant to thermal shock.

A comparison of the properties of the new product with fused quartz and previous low expansion glass may be drawn from Table X.

TABLE X

COMPARISON OF PHYSICAL PROPERTIES[46]

	New Glass	Previous Loss Expansion Glass	Fused Quartz
Softening Point	1442°C	819°C	1667°C
Annealing Point	931°C	553	1140
Strain Point	857	510	1070
Max. temp. for use (for considerable period)	900° to 1000°C	500° to 600°C	1100°C
Specific Gravity	2.18	2.23	2.21
Linear Expansion Coefficient (°C)	7.8 to 8x10^{-7}	32-33 x 10^{-7}	5.5 to 5.85x10^{-7}

Among the recent interesting developments is a series of optical glasses invented by G. W. Morey[47]. These newly discovered glasses are inorganic, non-silicate, amorphous substances. Morey found that judicious choice of rare earth oxides in combination with boron and sodium permitted the development of glasses with unusually

high refractive indices and comparatively low relative dispersions. In ordinary silicate glasses with an index of refraction above 1.65, the dispersions are a definite function of the index, but Morey's new glasses avoid this difficulty. Interesting examples of these, with the optical properties, are given in Table XI.

TABLE XI

COMPOSITIONS AND PROPERTIES OF NEW OPTICAL GLASSES[47]

	30	31	32
Lanthanum Oxide	42	20	28
Zirconium Oxide	6	....	....
Titanium Oxide	12	....	....
Tantalum Oxide	28	....	28
Boron Oxide	12	40	22
Strontium Oxide	....	....	....
Thorium Oxide	....	20	14
Barium Oxide	....	20	....
Lithium Nitrate	....	....	8
Ref. Index for C	1.996	1.6820	1.8060
Ref. Index for D	2.008	1.6861	1.8119
Ref. Index for F	2.036	1.6839	1.8258
V	25.2	58.0	41.15

The list of glasses for special purposes is a long one. Daylight glass has come in for attention from Gage, Rising, and Gelstharp and Sherts. X-ray absorbing glass is disclosed by Long, Gelstharp and others. Combinations of heat resisting and daylight properties have been worked out. Refractory glasses for use in place of quartz in heavy duty mercury arc lamps are available.

The advent of "Neon" signs stimulated the development of special fluorescent glass tubing, as well as the preparation of coatings of fluorescent material for use with conventional glass tubing. Improved glasses for a wide variety of glass-to-metal seals have been worked out. Special compositions for glass fibers have received attention. There seems to be no end to the possibilities in the use of glass for special purposes, but despite these newer developments, it is worthy of note that silica, lime and soda still form over 90 per cent of the content of almost all of the glass made the world over.

[1]W. E. S. Turner, *J. Soc. Glass Tech.* 12, 134-8, 1928 and M. Parkin, W. J. A. Warren, and W. E. S. Turner, *J. Soc. Glass Tech.* 15, 153-166, 1931.
[2]A. E. J. Vickers, *J. Soc. Glass Tech.* 15, 166-172, 1931.
[3]U. S. A. Patents 1,665,693; 1,665,694; 1,962,495; 1,962,496.
[4]U. S. A. Patent 1,694,831.
[5]U. S. A. Patent 1,925,381.
[6]U. S. A. Patent 2,020,467.
[7]U. S. A. Patents 1,986,720; 2,113,195; 2,116,623.
[8]*Feldspar as a Constituent of Glass.* Nat. Felds. Assoc., 1937. Edited by Donald E. Sharp.
[9]Furnished through courtesy of Great Lakes Foundry Sand Company, Detroit, Michigan. (Private Communication).
[10]Furnished through courtesy of New England Nepheline Company, Keene, New Hampshire. (Private Communication).
[11]Furnished through courtesy of V. V. Kelsey, Dominion Minerals, Inc., Washington, D. C. (Private Communication).
[12]D. E. Sharp. *J. Ind. & Eng. Chem.* 25, 735 (1933), and *Modern Glass Practice*, S. R. Scholes. Pub. by Ceramic Industry, Chicago, Ill.
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LIBBEY GLASS CO. RE-ENTERS FINE ART-GLASS FIELD

Return of the Libbey Glass Co. to the production of fine off-hand table and artistic glassware was signalized by an Exposition of Modern American Glassware, held at the Hotel Gotham, New York, on Wednesday, March 27. The important event was celebrated with appropriate and elaborate ceremonies, in which distinguished artists, patrons and connoiseurs of art, glassmen and representatives of class publications participated.

Edwin Fuerst, designer for Libbey Glass Co., gave a short address in which he outlined the principles underlying the design and production of fine, hand made ware of this type. Following this, several outstanding specimens from the collection were presented by beautifully gowned models. All the while a commentator traced the history of American glass and described the inspiration behind each particular design.

Among the glassmen present were W. E. Levis, J. Preston Levis, H. K. Boeschenstein, S. J. Solon, J. H. Wright, U. V. Bowes, T. K. Almroth, R. W. Rogers and Thomas Walker.

The roots of the Libbey Glass Co. reach back almost a century and a quarter and the company has been identified with several of the major phases of the development of fine American glassware. William E. Libbey, founder of the Libbey Glass Co., learned the art from the New England Glass Co. and he eventually bought that concern, which played so important a role in the early history of this country.

When the plant was removed from Cambridge, Mass., to Toledo in 1888, Edward Drummond Libbey was president of the company and he maintained the tradition of producing a quality ware which had been characteristic of the line from the beginning. It was in those days that Edward Libbey made a ceremony of throwing twenty-dollar gold pieces into the furnace when making ruby glass. This same Edward Libbey later founded the Toledo Art Museum, endowing it with many rare specimens and supporting the institution financially.

In 1893, the Libbey Glass Co. made an investment of $250,000 in an exhibit of cut glass at the Chicago World's Fair, which brought American cut glass into international prominence. At the same time the company created a sensation by producing a spun-glass dress for the Infanta Eulalie of Spain.

20 YEARS OF PROGRESS IN GLASS PLANT MATERIALS HANDLING

By F. E. BARDROF

The shovel, the wheelbarrow and the handcart predominated over all other types of materials handling equipment in the glass plants of twenty years ago. Manufacturing processes were intermittent in their nature, productions rates were low as compared with the present, and the problem of handling enormous quantities of raw materials, mixed batch and finished products continuously and efficiently had not yet appeared. During the past two decades, however, the development of equipment and machines for continuous melting, feeding, forming and annealing has changed the whole aspect of the glass manufacturing plant completely. With single melting units producing from 50 to 120 tons of glass daily, manual handling methods have become entirely inadequate and have been quite largely replaced by power-driven materials handling equipment of various types.

The transformation from the old man-power "glass-house" to the modern stream-lined glass factory of today is characterized by the use of materials handling machinery, as well as by the application of modern manufacturing equipment. Many early applications of handling equipment were somewhat crude and were unable to cope with later increases in production, the result being that such installations have either been replaced or are now heavily overloaded in an attempt to keep up with the requirements. Another factor which has necessarily received more attention during the last two decades is the dust hazard, and the elimination of this hazard has been the objective of handling-equipment installations already made or in preparation. It is probably true that applications of modern materials handling equipment of one kind or another can be made to advantage in the great majority of present-day glass manufacturing plants, and this holds true quite irrespective of their size.

Fuel Handling

Equipment for handling gaseous and liquid fuels does not come within the scope of this article, but attention should be given to methods for handling coal in plants fired with producer gas. Operations include unloading from carriers, elevation to storage, and conveying; the equipment used in glass plants being similar to that for the same purposes in other industries. An installation for unloading and handling coal from barges in a Baltimore plant is shown in Fig. 1, the unloading operation being performed by a bucket crane which does not appear in the picture. The bucket deposits the coal in an elevated hopper from which an inclined belt conveyor delivers the fuel to storage bins in the top of the producer house.

A typical coal-handling plant for railroad delivery is shown in the view of the producer plant in Fig. 2. Here the coal is dumped into a track hopper, carried to the bottom of the elevator boot by a short horizontal conveyor, and finally elevated to the storage bins at the top of the building. An important adjunct to such a railroad installation is a motor-driven car-puller, one of which can be seen beside the track at the right-hand corner of the building. At the top of the house a horizontal conveyor with a traveling unloader delivers the coal to the desired bin.

Fig. 1. In this installation of coal-handling equipment, a coal barge is moored beneath the steel framework and the coal is transferred to the conical hopper by a grab bucket. The hopper discharges upon the belt conveyor which ascends to the top of the producer house in the background.

Fig. 2. Another coal-handling installation, in which the fuel drops from a railroad car into a track hopper from which it is elevated to storage bins at the top of the producer house. An important accessory is the motor-driven car-puller at the corner of the building to the right.

Fig. 3. This traveling type of elevator receives raw materials from the railroad car and delivers them through an inclined chute to any one of several storage bins. This particular arrangement has its own independent dust-collecting system.

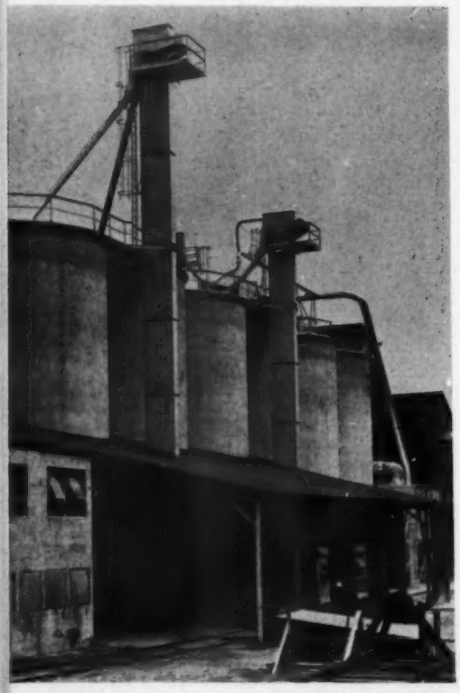


Fig. 4. This view of a modern batch house shows the use of fixed elevators receiving raw materials from track hoppers and delivering to particular storage bins. An interesting feature here is the application of dust-collecting ducts.

Fig. 5. This view in the gallery above the storage bins shows how a single elevator may discharge to any one of several bins through a shuttle conveyor.

Raw materials used in large quantities are usually received in bulk railroad shipments and the first job is to get them out of the car, some kind of a power shovel being used in many plants to shove the material into a hopper at the side of the track. The next operation is to transfer the material from the hopper to the designated storage bin, elevation to the top of the batch house being required in most instances. The job can be done in several ways, such as by a traveling elevator which can deliver to any bin, stationary elevators serving particular bins only; or by one or more elevators discharging to a shuttle conveyor, which in turn delivers the material to any desired bin. Selection of proper combination of equipment depends on type and location of bins and the amount of materials to be handled in a given time.

A traveling elevator which delivers to any one of several storage bins is shown in Fig. 3. A short horizontal belt conveyor carries the materials to the bottom of the elevator and a chute leads from the top of the elevator to the opening in the circular steel storage tank. Motors for the elevator and the power shovel are located in the house at the level of the upper guide rail. An important auxiliary is an independent dust collector system carried on the far side of the framework near the bottom.

An installation of stationary elevators serving particular bins is shown in Fig. 4. Here a power shovel unloads the material into a chute which leads to the bottom of the elevator boot and tubular chutes carry the material away at the top. A suitable shed protects car-unloading operations from the weather. The elevator in the foreground handles sand and delivers to either of the first two bins through one of two delivery chutes. The second elevator serves segments of the next two bins, its discharge chute leading to a radial, movable, horizontal conveyor which can deliver to the desired bin segment. The last two bins are for cullet storage and are served by elevators on the other side of the building. In this installation dust collector pipes lead from the tops of the elevators to a central dust-collecting system.

Fig. 5 shows another installation, in which a shuttle conveyor above the circular concrete bins receives all materials except sand and cullet from a stationary elevator and delivers to any one of the series of bins. In this application the dust hazard is decreased by carefully enclosing all parts of the handling machinery. In this plant cullet is stored in a bin near the furnaces and sand is handled by a separate elevator direct to the sand bins.

Cullet Handling

Cullet handling involves collection and transportation from the points where it is produced, crushing, and storage. Whether a conveyor of the pan type shall be installed to remove cullet produced at any point depends entirely on the rate of production at that point, and for small quantities a hand or truck-operated cart may be used. For large quantities, however, a pan conveyor is usually installed and a water spray is arranged for hot cullet to help break it up. In any event, the cullet is delivered to a crusher and then carried to a storage bin by a belt conveyor, or an elevator, or a combination of both. In large plate-glass plants where cullet originates on the capping table at the far end of the lehr, the conveyor from crusher to storage must often be very long and in one plant this belt conveyor has a length of 670

ft., part of which is inclined to bring the cullet to storage bin level. Fig. 6 shows three cullet elevators leading to storage bins in a large plant that manufactures colored glasses and in which the segregation of cullets is necessary.

The handling of "foreign" cullet after crushing is similar, except that the broken glass is generally passed through a cleaning apparatus before crushing.

Batch Weighing and Collecting

The last twenty years have seen the development of manual, semi-automatic and fully-automatic equipment for the weighing and collection of batch materials, the objectives in a modern system being accuracy in proportioning and elimination of the dust hazard. In each system the fundamental operations are the weighing of each ingredient and the collection of all weighed ingredients before delivery to the mixer.

The manually-operated systems generally involve the use of a batch car of some kind, carrying a hopper in which the batch materials are collected. The car shown in Fig. 7 is of the trolley type and runs on a track in front of the storage bins, this particular installation having a single scale mounted on the car. The operator is controlling the flow of sand through the bin gate, the gate being surrounded by a hood which connects to a central dust-collecting system. When all materials have been collected the car is run to a position at the mixer and the contents of the hopper are dumped into a skip hoist for elevation to mixer level.

In another manually-controlled, batch-car installation, shown in Fig. 8, a stationary weigh-hopper is suspended beneath each bin gate and connected to a stationary scale on the floor, a separate scale being furnished for each ingredient. The batch car travels on a tramrail beneath the weight hoppers and collects each ingredient in turn. In this case the entire batch car is elevated to the mixer level for dumping.

Both the semi-automatic and automatic weighing and collecting systems utilize a belt conveyor in a dust-proof housing, instead of a hopper car, for collecting the ingredients. The collector belt ordinarily delivers to an elevator which, in turn, discharges into a surge bin from which the batch is finally dumped into the mixer. Each system also has a weigh-hopper beneath each bin, each hopper being connected to a scale located on the floor nearby. In the semi-automatic system the weigh hoppers are filled and emptied by manual operation of gates, the time for emptying being indicated by a signal light controlled from level indicators in the surge bin.

The automatic system utilizes electrically-operated feeders to fill and empty the weigh hoppers and a portion of such a system is shown in Fig. 9. Here the conical weigh-hoppers deliver to the enclosed continuously-running collector belt conveyor, the belt discharging to a continuously-running elevator which rises at the far end of the gallery. All of the filling feeders are started at once from a control desk and each is automatically stopped by its scale mechanism when the proper amount of material has been fed into the hopper. The emptying feeders are interlocked with surge bin level indicators and with each other so that they will not operate unless the surge bin is empty and every hopper is filled with the proper amount of material. With all conditions right, the feeders deliver to the belt and the batch is collected in the surge bin ready for the mixer.

Mixed Batch Handling and Transport

Power-driven mixers are now universally used for mixing batch materials, most of these mixers being of the rotating-barrel type, although the pan type of mixer is gaining acceptance. Models which tilt to empty and others which are emptied by swinging shovels are both found in various plants, and the provision of dust boots or other dust elimination means is becoming general. During recent years the use of magnetic equipment in the mixer discharge has become quite general for removing tramp iron, and many plant engineers believe that such safety insurance is a necessity in every batch system. A typical application of a magnetic pulley is shown in Fig. 10. Here the mixer discharges into a bin and then

Fig. 6. Here can be seen the housings of three elevators, each serving one cullet storage bin. These tight housings and the dust hoods over the bin-discharge gates in the background indicate the care taken to eliminate the dust hazard.

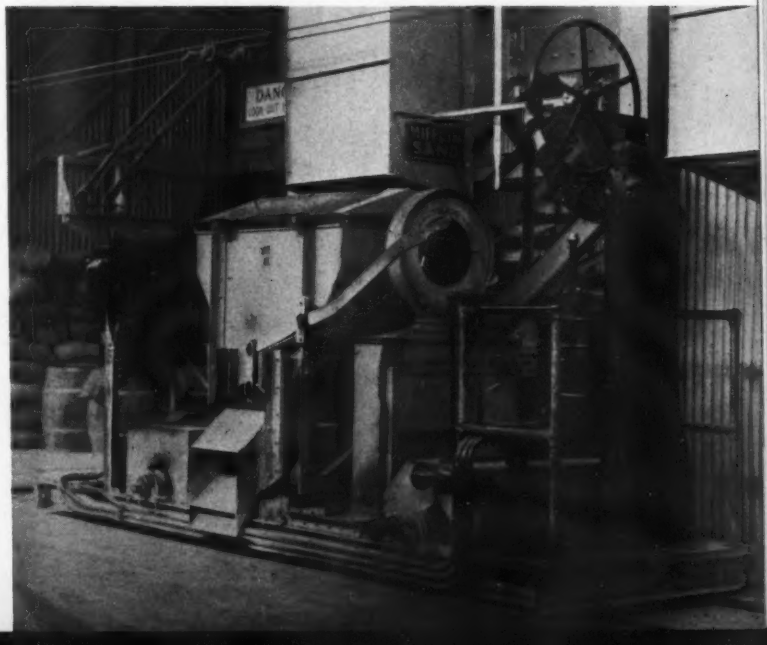


Fig. 7. Batch-collecting car of the trolley type with weigh-hopper and scales. Note the hopper-discharge chute and the dust hood over the bin gate that is being manipulated by the operator.

Fig. 8. Another type of batch-collecting car which moves along a double tramrail and merely collects the materials from the stationary weigh hoppers suspended above. Note the stationary scales on the floor.

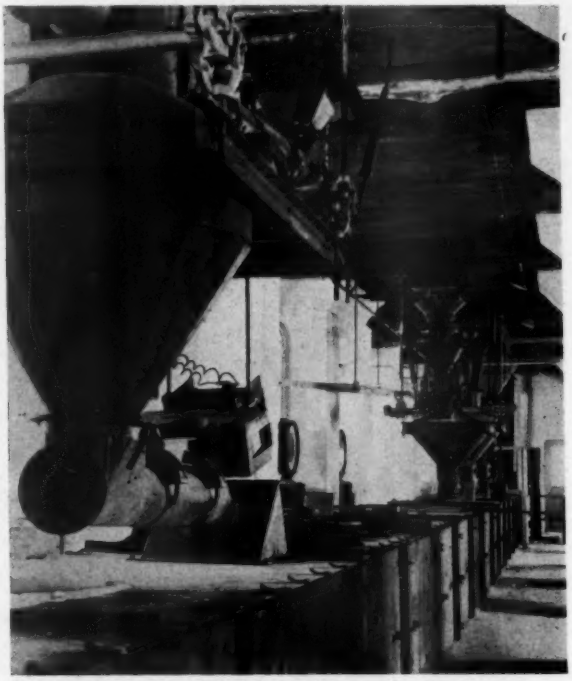


Fig. 9. An automatic batch weighing and collecting system. Here the conical weigh-hoppers are filled and emptied by electrical feeders of the vibrating type, the amount of material fed into the hoppers being controlled automatically by the scales in the background.

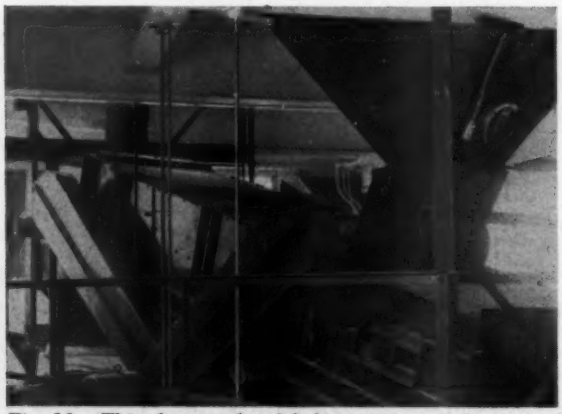


Fig. 10. This short enclosed belt conveyor receives mixed batch from the bin at the right and delivers it over a magnetic pulley at the far end into a batch bucket.

to a belt conveyor through the rotating feeder at the right. The belt passes over a magnetic driving pulley at the far end of the casing, where the iron is removed and the batch is delivered to the transportation system.

Twenty years ago mixed batch was transported to the furnaces in handcarts and batch wagons in practically all plants and they are still used in some factories, the material being shoveled from the cart into the doghouse. The next step forward in equipment for batch handling was the application of power-driven elevators and belt conveyors which discharge the batch into large storage tanks or bins near the melting furnaces. Some of these systems have given excellent service for many years and variations of such arrangements have been installed in modern plants built during the last few years. In some instances, however, trouble was experienced from segregation and dusting. Special efforts have been made to keep conveyors tightly enclosed and to provide baffle plates in such storage tanks to reduce segregation in the outward-flowing batch.

In recent years the use of unit containers of the bucket type for transporting mixed batch has grown rapidly. These unit containers are usually designed to hold one complete mixer load, the material remaining quiescent in the bucket from the time it leaves the mixer until it is discharged at the melting furnace. Advantages claimed for transport of batch in buckets include reduction of segregation, practical elimination of dust, and improved storage facilities. Batch buckets are transported in several ways, such as industrial trucks or tramrail systems of the manually-operated, crane-type, or automatic style.

A specially designed industrial truck for batch bucket transport is shown in Fig. 11, this bucket being handled by truck to the platform elevator serving the furnace room. In the furnace room the bucket is picked up by an overhead crane and deposited at the furnace. At another plant a variation of this method is found in the use of a three-wheel trailer drawn by a gasoline tractor, the bucket being placed on the trailer at the batch mixer and drawn to a position in the furnace building from which it is handled further by a tramrail electric hoist.

Complete tramrail systems leading all the way from the batch house to the furnaces have also become popular, since such systems do not require valuable floor space and are easily adapted to storage arrangements, either on the rail or in a specified area of floor or basement. Fig. 12 shows a tramrail system in which the buckets are pushed around by man-power. In this installation the filled buckets are stored on the rail as shown and pushed along to the tank as required. At the tank a hoist raises the bucket to a tramrail loop above the charging floor. Variations of this arrangement are used in a number of small plants.

Another type of tramrail installation incorporating a traveling hoist is shown in Fig. 13. In this view at the rear of the tank in a large plant the hoist has just placed a bucket on framework above the doghouse hopper and the contents are being discharged. The operator rides in a cab attached to the hoist. In this system the loaded batch buckets are stored on the floor of the gallery between the furnace room and the batch house, seen through the large doors in the side of the building.

A popular method for batch transport during recent years has been to gather several batch buckets in a train

and drag them along a tramrail by means of an electric tractor. In some of these installations the tractor is manually controlled, the operator walking along beside the batch-bucket train with the control button in his hands. A further refinement of this arrangement is the addition of automatic control for train movements, and Fig. 14 shows a recent automatic installation in which the tramrail makes two loops, one at the furnace and one at the loading position. Between the loops the tramrails are divided into sections or blocks, so arranged with limit switches that a train cannot enter a given block until the preceding train has passed on. Movements at the filling and unloading positions are manually controlled, Fig. 14 showing one of the trains at the loading position. It will be evident that in this arrangement the filled buckets are stored on the rail.

Fig. 11. A specially-designed industrial truck for transporting mixed batch to the furnaces in buckets.

Fig. 12. View in a small plant showing mixed batch stored in buckets on a tramrail. Buckets are pushed along the tramrail to the furnace by hand as required.

Furnace Charging

Many glass furnaces are still charged manually, the batch being either shoveled or delivered to the doghouse from a small hopper by a chute with a hand-operated gate. Other plants use batch chargers of special design, such as the screw conveyor type or the straight pusher type that can be seen in Fig. 13. Some chargers have come into sufficiently general use to be considered standard equipment and are offered in the market by machinery manufacturers. A popular mechanical charger, known generally as the H-A feeder, is shown in Fig. 15, this particular installation being of the double type serving two doghouses located side-by-side at the rear of the furnace. It will be noted that this plant utilizes batch buckets, filled buckets being placed on the charger by means of a tramrail hoist.

Another style of batch charger that is becoming quite popular is the electrical feeder of the vibrating type, shown in Fig. 16. In this installation the batch bucket is positioned on a tramrail above a hopper, from which the batch flows through a chute to the water-cooled pan of the feeder which, in turn, discharges into the doghouse. The electrical mechanism of this feeder is exactly similar to the material feeders shown in Fig. 9 and the operation is easily and accurately controlled.

Dust Collecting

In most states legal restrictions against silica dust conditions are becoming more and more rigorous, the upshot being that the batch houses in many glass plants have been or must be revamped or rebuilt to decrease this hazard. The fully-automatic batch handling and mixing systems can be so completely enclosed that practically no dust is emitted at any stage of the proceedings. In other types of batch systems, however, some method of collecting dust at certain points must usually be considered. Application of dust hoods and ducts have already been indicated in the foregoing discussions of batching equipment and the central collector for one of these systems is shown in Fig. 17. This particular collector serves every piece of batching equipment, from the raw material elevators to the filling chutes for the batch buckets.

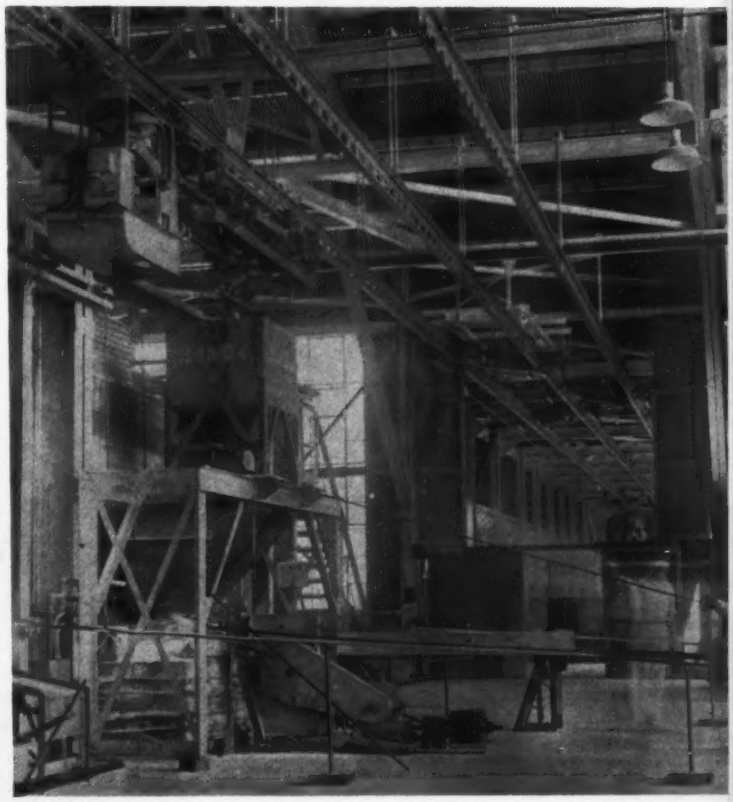


Fig. 13. In this large plant batch buckets are handled by a tramrail hoist. This view shows the hoist at the upper left with a batch bucket above the doghouse hopper. Filled buckets are stored on the floor of the gallery seen through the large doors in the background.

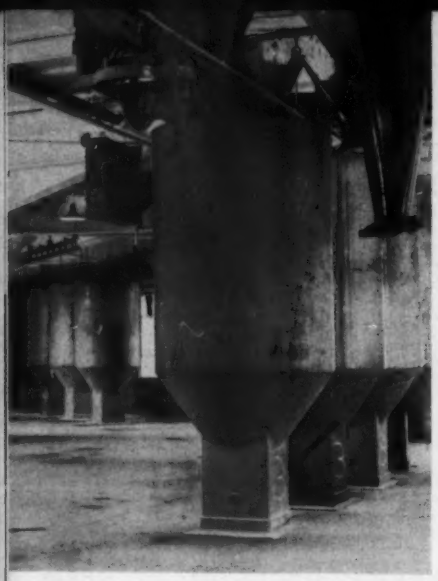


Fig. 14. An automatic tramrail system in which six-bucket trains are pulled by tractors. A block system automatically controls the movement of the trains. Here the second bucket in the train in the foreground is being filled with batch.

Fig. 15. An installation of the well-known H-A feeder for charging batch into the furnace. This double feeder serves two doghouses and the batch is brought in buckets by a tramrail hoist.

Miscellaneous Handling Equipment

Up to this point, the development of equipment for handling fuel and raw materials in glass plants have been considered and, although such applications make up the majority of the uses, there still remain many other points in the production lines of different plants in which the judicious application of materials handling equipment can be of definite advantage.

Of considerable importance is the use of conveyors of the belt and roller type for the handling of finished ware. Most applications of this type are of comparatively recent origin and they are quite uniformly successful in serving the inspection, packing, storage and shipping departments. In most of these systems an endeavor is made to have at least a portion of the equipment more-or-less portable, so that it can be changed around to suit production requirements when necessary. Among the possible advantages from such systems may be mentioned increased speed, reduced breakage and lower handling costs.

Traveling cranes are now used quite extensively in flat-glass plants for handling the product in quantities and for the transfer of heavy pots or other equipment and machinery. As a matter of fact, the use of cranes and hoists of various types and sizes for handling heavy machine parts and moulds has grown rapidly in recent years with the installation of production machinery of the heavier automatic sort. In one plant an interesting hoist application includes an I-beam rail with one end pivoted above the center of the semi-circular nose of the furnace. The rail can be swung so that its outer end is located above any one of the feeders and machines at the front of the tank, and a movable hoist on the rail can be used to pick up machine parts of moulds as desired.

Although the possible and potentially profitable uses of modern power-driven materials-handling equipment in and about the glass plant are almost innumerable, the trend toward such standardized machinery may be said to have only begun. However, the standardization of materials, products and processes, together with increased productive capacity and higher standards of quality, are making the use of handling equipment almost a necessity. And, with the increasing application of these devices, glass manufacturing departs further and further from the old-time, man-power glasshouse and approaches the streamlined facility of a modern process industry.

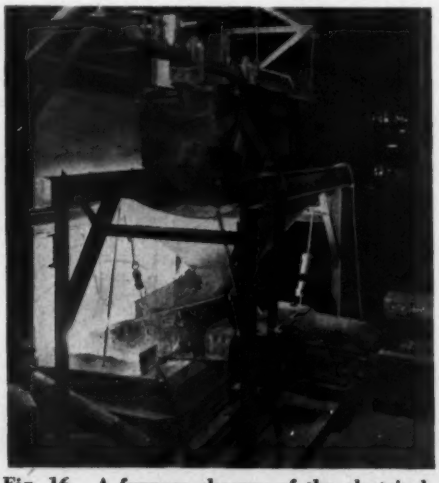
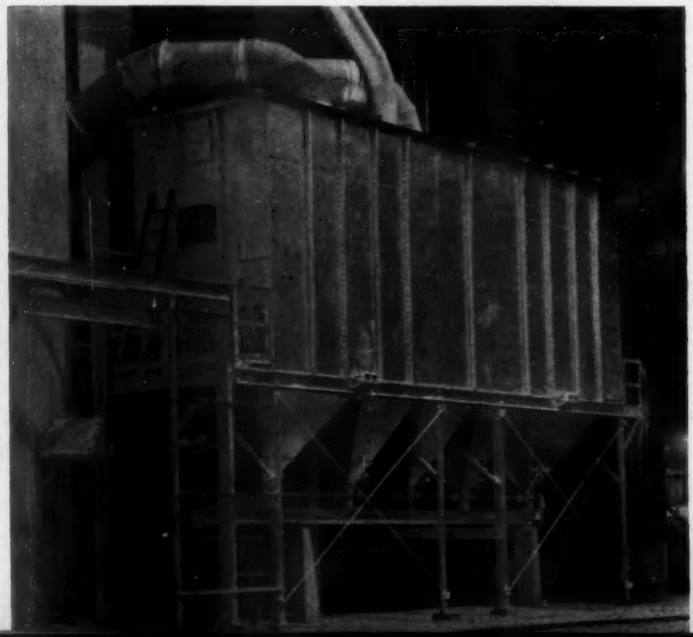


Fig. 16. A furnace charger of the electrical, vibrating, pan-feeder type. Batch is discharged through a chute from the tramrail bucket to the water-cooled pan of the feeder.

Fig. 17. Central dust-collecting system for a large batch house. This collector serves all batching equipment from the raw material elevators to the batch-bucket filling chutes.



20 YEARS OF PROGRESS IN GLASS MELTING

By F. G. SCHWALBE
Toledo Engineering Co.

When glassware was made by hand the melting rates of the furnaces were not very high, costs for fuels were comparatively low and there was little incentive to spend money for furnace improvements. As a result, furnaces followed the same pattern of design and construction for many years. But with the introduction of semi-automatic, hand-fed machines, improvements in glass-melting furnaces became necessary, and an era of change and development was initiated that has continued to the present day. The first effect of the early machines was to increase the amount of glass taken from each gathering opening and, of course, the total tonnage melted. The increased melting rate, in turn, called for closer regulation of the furnace temperatures, and there began a wider use of the simpler types of temperature indicators, usually the installation of a single thermocouple in the melting-end crown. The gathering boy's cry of "Soup" was the indication that the working end was running too hot.

Twenty years ago many furnaces were still fired direct, but the regenerative side-port or end-port designs were also becoming accepted. Continuous melting had been developed with machines of the Owens suction type, but hand-gathering still was in use in most plants and furnace development lagged. The decade that followed, however, brought forth unprecedented developments in automatic forming machines and feeders, these improvements necessitating quite radical changes in the design, construction and operation of the melting furnace. Superficially, the modern continuous melting tank does not differ widely in appearance from the tanks of twenty years ago; although the average furnace today sets up higher than its surroundings, its general construction features are quite similar. When examined in detail, however, the modern furnace is found to be immensely improved over its prototype and its efficiency and operating life are almost beyond comparison.

Checker Volume Increased with Furnace Height

The first far-reaching effect of the installation of automatic machines and feeders was to boost the metal line in the tank much higher above the factory floor, this change being necessitated by the height of the machines and the distance needed for gravitational flow from the feeders. This requirement was directly responsible for a great improvement in furnace design, because the increased furnace height was used in the checker chambers, thereby bringing about increased heating efficiency and lower fuel rates per ton of glass melted. In 1920 a furnace with a checker depth of 8 feet was considered good, but the additional 4 feet which the new machines required, improved the checkers from an operating standpoint. Today, still greater elevations between the factory floor and the glass line are found and furnaces are now in operation with checker depths of 18 feet.

The advent of automatic feeding devices, operating within certain temperature limits, loaded the melting furnaces with new operating requirements that had an effect on all phases of design, construction and operation. First, the greatly increased production rates necessitated greater melting rates; second, it became necessary to hold furnace temperatures closer than ever before and operators found that temperatures in other parts of the furnace as well as at the melting end were important; third, it was necessary to maintain a constant level of glass in the furnace. No single development could solve all of these problems and the improvements introduced into modern glass furnaces have included such diversifications as refractories, instrumentation, automatic control, furnace proportions, fuels and combustion, and operating technique. These advances have also made it possible to produce glass of better quality and the modern furnace now must meet a high standard for glass quality, as well as for production rate and operating cost.

Melting Rates Tripled

The average melting furnace of twenty years ago on container glass would require about 16 sq. ft. of melting area per ton of glass produced. If this rate were exceeded trouble usually resulted in the form of poor glass quality and rapid deterioration of refractories. Today, container glass melting rates as low as 4.5 sq. ft. per ton are regularly reported and a similar increase in melting rates has been accomplished in sheet and plate glass furnaces. Along with the increased melting rates have come higher operating temperatures. In 1920 average melting temperatures ranged from 2,550 to 2,600 deg. F., but today's melting temperatures range all the way from 2,700 to as high as 2,900 deg. F. and this increase of course places an extra hardship on furnace refractories.

In spite of harder service on refractories, the operating life of melting furnaces has been materially lengthened, due to the remarkable strides made in the quality of refractory materials used both in the upper structure and below the glass line. Twenty years ago the heating campaign on a continuous tank lasted for only a few months, but today it is not uncommon for a furnace to run for more than two years with only minor repairs. Basically, little change has taken place in the selection of materials for furnace construction. Silica is still the standard upper structure material and fireclay brick is generally used for ports and regenerators. Modern refractories are made very uniform in size and shape, thus effecting considerable savings in construction labor costs.

Super-refractories are also available for use in the upper structure and when properly used show a good return on the added investment. Super-refractory materials are often misused, however, in an attempt to overcome local deterioration, whereas the proper procedure would be to eliminate the cause by changing the design or the operating technique. It is often difficult to draw the line of demarcation between improper design and improper use of materials.

The introduction of electrically fused and cast refractory material was the spark that set off the race toward better furnace lining refractories. When electrically fused

blocks first appeared on the market they were so much superior to any materials previously available that a ready and eager market awaited their use. These blocks are very dense, with a weight of approximately 187 lb. per cu. ft. Following the advent of these materials, rapid improvements were also made in the quality of burned flux blocks. Both types of material are in use today and each type of block has its advantages for certain locations and conditions.

Use of Instruments in Furnace Operation

The past twenty years has witnessed an increasing tendency to control furnace conditions by means of instruments, either automatically or manually in accordance with instrument indications. This trend was brought about by increased fuel costs and by the necessity for maintenance of uniform conditions in the furnace. In common use are indicators and recorders of temperatures in the melting end, working end, checkers and flues, and in furnace pressure. Also used in increasing numbers are meters for fuels and combustion air, and fuel-air ratio meters, especially in installations where the combustion air is supplied by a fan. The use of fan air for combustion is becoming more and more common, because it permits more accurate control under all load conditions and usually a higher maximum melting capacity in the furnace. Some modern furnaces are now being equipped with instruments which indicate the temperature difference between the checkers and which signal the operator when the proper time comes to reverse the furnace.

Full automatic control of glass melting furnaces lags somewhat behind other industries, but it may become more widely accepted when the variables in the furnace operating problem become more nearly standardized. However, automatic damper regulators for the control of furnace pressure are becoming almost commonplace and automatic regulation of the fuel-air ratio is proving successful. Automatic control of the furnace temperature and of the reversal operation seem to offer possibilities for the future. In producer gas installations, automatic control of the producer operation is almost universal at the present time.

Cooling and Insulation

Cooling of side-wall blocks has become general with the increase in melting temperatures and the great majority utilize air as the cooling medium. Special nozzles have been developed expressly for this purpose and have raised the efficiency and effectiveness of block-cooling systems materially. Some parts of the upper structure are also being cooled effectively. The loss of heat from the glass furnace by radiation is enormous and the use of insulation at certain points to reduce these losses is also proving successful. Insulation of regenerator and flue walls is now an accepted practice and furnace crowns are also being successfully insulated. Attempts to insulate the refractories below the glass level show some promise, but more development work is needed before this can be done successfully.

The three commonly used fuels of today are natural gas, producer gas and oil, utilization of the latter being on the increase at the present time. A comparatively recent development is the installation of propane or butane systems for standby service. Each fuel requires a specific design of furnace, but the difficult problem of designing a furnace which will use oil as a fuel with gas as a standby, or vice versa, has also been successfully solved.

Combustion of Gas and Oil Fuels

The effect of greater checker depth on combustion efficiency has already been mentioned, together with the results of instrumentation. Other combustion developments include the method of firing by which natural gas is caused to burn with a luminous flame, taking full advantage of this clean high heating value fuel. Many plants in the midwest that formerly used coal or oil are now supplied with natural gas by recently built pipelines from the producing fields and plants located along the Atlantic and Pacific coasts comprise the major users of oil for glass melting. Oil-fired furnaces are mostly of the regenerative type and differ only in the method of introducing the fuel, the modern method being to locate the burners either below or above the ports or in combination. Present-day designs aim to eliminate flame impingement on the refractories and to obtain maximum flame coverage of the glass surfaces. There is still a great variation among different plants in types of burners and such details as oil pressures and handling methods. Reports from some oil-fired installations give an average fuel oil consumption of 45 to 50 gallons per ton of glass melted.

Considering general furnace dimensions, it has already been noted that the ratio of checker volume to melting area is on the increase. There has also been a tendency to decrease the glass depth, especially in furnaces for the production of sheet and plate glass. Practice in the design of throats is divided between the straight and sunken types and, although the throat of a tank continues to be a source of trouble, the use of better refractories has definitely improved the operating life of this section of the furnace. The newer refractories have also decreased deterioration of the furnace walls near the doghouse.

Side-port and End-port Types

The side-port type of furnace continues to be most widely used because of its superior temperature gradient in the melting end. End-port furnaces are limited in capacity by the available port area and are generally built for capacities up to about 45 tons, although a few larger tanks of this type are in successful operation. Most end-port installations are of the regenerative type although recuperators were quite popular at one time. However, at no time did the recuperative furnaces comprise as much as 10 per cent of the total and their use seems to be dying out at present.

Although the idea is not new, there have been several applications during the past few years of individual port control on side-fired regenerative furnaces. Another step in this direction is the incorporation of a type of open-hearth furnace equipment for draft and combustion air control on each port. Still in the experimental stage are somewhat radical designs in which a chamber is provided for melting and a second chamber for plaining of the glass, the two chambers taking the place of the conventional melting end. (*Continued on page* 202)

20 YEARS OF PROGRESS IN GLASS-FORMING MACHINES—I

MACHINES FOR CONTAINERS AND OTHER GLASSWARE

To avoid confusion in following the development of forming machines for glassware, it is well to divide them into groups of similar machines, as follows: (1) Glassware presses, (2) Press-and-blow machines, (3) Narrow-neck machines and (4) Paste-mould machines.

Glassware Presses

The old, familiar form of glass press was the "side-lever" hand press. Though still in use 20 years ago, the march of time has gradually rendered it obsolete, until today its only important function is to manufacture specialties on a small scale. This side-lever press had a single vertical pressing plunger carried on a crosshead that was actuated by cranks beneath the table. This shaft, in turn, was worked by a huge side lever of peculiar shape, having what was termed a "knee." After a gather of glass was placed in the mould by a gatherer with a hand punty, the presser cut it off with hand shears and pushed the mould to the pressing position under the plunger, generally placing a mould ring on the mould as he did so. He then grabbed for the "knee" of the side lever which was just within reach, the end of the lever being away up in the air. Lowering the plunger into the mould brought the lever to a more nearly horizontal position, and the presser could grasp the end of the lever to exert increased pull on the plunger. The pull was further increased by the cranks being set, as the pressers would say, "on the bite," or in dead-center toggle position.

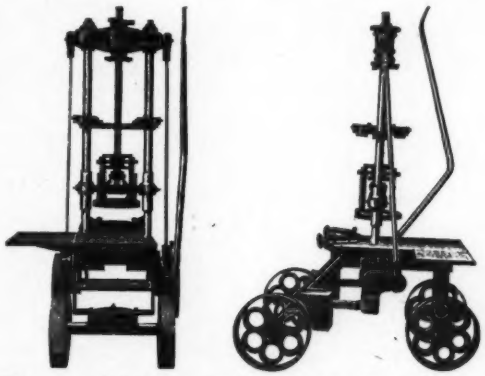


Fig. 1. Side-lever hand-operated glassware press without plunger or moulds. Note long side lever with "knee" and heavy counterweight on crank. Illustration courtesy Sommerfeld Machine Co.

In steady production these presses were generally operated with a pair of moulds and, while one mould was being used for pressing, the other was pulled to one side under an air blast. This air blast cooled the article, which was then "turned out" by inverting the mould and tapping on the mould valve.

The next step in press development was to convert the old side-lever press into a multiple machine. This was accomplished by placing several moulds on a small turntable, with a lock that held each of the moulds in turn accurately under the plunger. Here the gathering was by hand, and, at first, a side lever was used to work the plunger. Then a steam cylinder was developed to actuate the plunger, and eventually air was utilized. Air was also applied later to index the table automatically. When the automatic glass feeder came into use, the presses, of course, had to be improved so that they would operate with the necessary regularity and reliability.

Various presses improved to suit the new conditions were made to some extent in cooperation with feeder

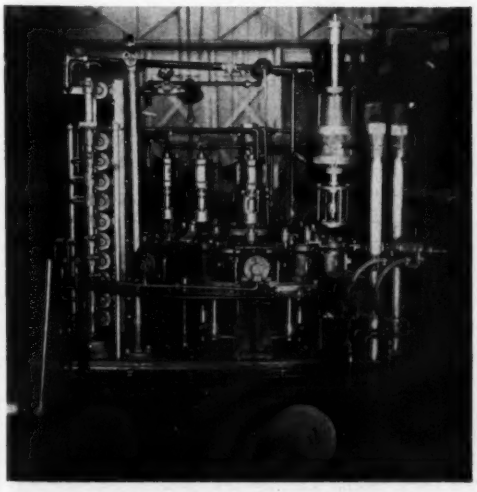


Fig. 2. A modern type of press-and-blow machine for wide-mouth ware. It carries 12 moulds and operates at a top speed of 50 pieces per minute. Photo courtesy Sommerfeld Machine Co.

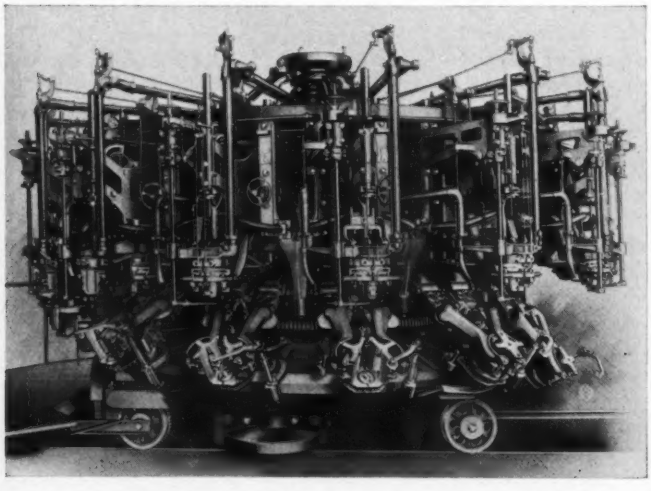


Fig. 3. A 15-arm Owens suction-type bottle machine with gathering position at right and blowing stations at the left. The Owens was the first completely automatic machine for the manufacture of narrow-neck bottles.

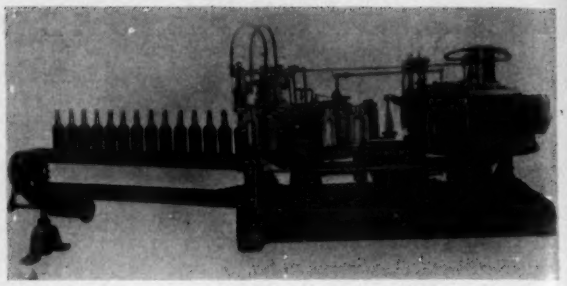


Fig. 5. (above) Lynch LA narrow-neck bottle machine with blank-mould turret at right and blow-moulds at the left. Here the parison is being held in the neck ring in readiness for the blow-mould to close upon it. Machine was air-driven. Photo courtesy of Lynch Corporation.

Fig. 4. O'Neill No. 25 narrow-neck bottle machine. Blank-mould turret at the left and blow-mould table at the right with radial parison transfer beween. Machine was completely air-driven.

manufacturers, as by Frank O'Neill, George Cleveland, Edward F. Miller, William J. Miller, Sommerfeld Machine Company and the then Hartford-Fairmont Company. Possibly there were others also, The Hazel-Atlas Glass Company also developed for its own use many presses which were not furnished to others.

Press-and-blow Machines

As with the modern press, the press-and-blow machine was also an outgrowth of the old side-lever press. This old press had been used at times to form by the normal pressing method, what was then called a pre-pressed blank. This blank was removed from the press mould and, either with a neck ring or with tongs, set over into a blow mould, where an operator pulled a blow-head down on it and blew the article. The first improvement on this system was the Teeple-Johnson machine which had two turrets, each mounting about three moulds and being locked in position at each station after being turned by hand. The machine was entirely hand-operated, requiring a gatherer and either two or three operators, according to the ware being made.

From this beginning came a growth to meet increased demands and conditions, just as in the case of presses. A great deal of improvement was made by Charles E. Blue, who not only used the Teeple press-and-blow arrangement, but also worked out the so-called "drop blank" system. In this system a telescopic blank mould sticks up into the blow mould and into contact with the neck ring. The charge is dropped through the neck ring, the mould is brought under a pressing plunger and the parison is pressed. As the plunger rises the blank mould drops away below the turn-table, leaving the finished parison suspended by the neck in the blow mould. A bottom plate slips in and the article is blown at a blow station, after which the mould opens and the article is removed. These operations were applied to automatic developments in various forms, using both intermittent and continuous turn-tables.

Another system, the "set-over transfer," was very much like the old Teeple-Johnson arrangement. Here the parison was pressed in a mould, automatically removed by tongs and set over into a blow mould, where it was blown as in the other system. This arrangement was applied to both single-table and double-table machines. In the single-table machines the blank moulds and blow moulds alternated; in the double-table machines the blank moulds are on one table and the blow moulds are on the other.

During the past twenty years a great many of these press-and-blow machines have been made, both air-driven and mechanically-driven and employing various combinations of mould arrangements, turrets, and mechanisms. A typical modern press-and-blow machine, built by the Sommerfeld Machine Co., is shown in the accompany illustration. This machine has 12 blank and 12 blow moulds. Its turret or table is rotated mechanically by a Geneva movement, while its plunger and various other auxiliary devices are actuated by air, everything being timed in unison by a vertical camshaft operating timing valves. This machine is capable of a top speed of 50 per minute for small ware and, of course, operates at lower speeds for heavier ware.

Narrow-neck Machines

The designation, "narrow-neck machine" is almost misleading, since these machines are now capable of making wider-mouthed ware. However, this type of machine was developed originally for narrow-neck ware, and for that purpose is distinctly a better machine.

Twenty years ago the Owens suction machine was in very extensive use, making a fairly wide range of ware both as to size and shape, although it did its best on narrow-neck bottles. In those days most Owens suction machines were of the six-arm type in which the entire machine would rise and fall as each mould was presented in turn over the rim of a revolving pot of glass, from which it obtained its charge and formed the parison by suction. The glass was cut off by a shear sliding across the lower end of the mould. The parison mould then opened and, while a machine turret rotated, the blow mould would rise up to enclose the parison which was then blown through the neck ring. The neck ring then opened and the blow mould dropped down again with the bottle within, after which the blow mould opened and a knock-out threw the bottle head-over-heels into a hopper. This

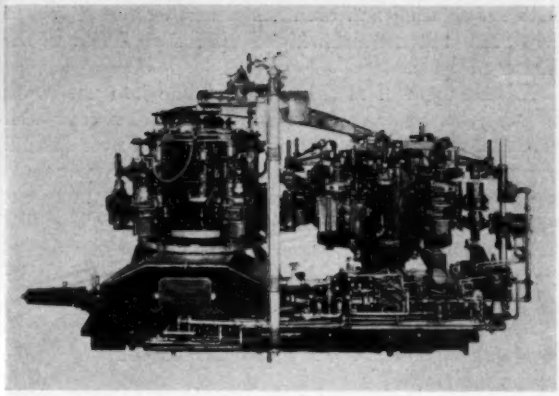


Fig. 6. Lynch Model 10 narrow-neck bottle machine. An improved model of the double-turret, air-driven machine, in which former limitations of cycle and speed were improved. Photo courtesy Lynch Corporation.

machine was later replaced by the improved individual dip machine with ten sections. Here, instead of raising and lowering the whole machine to dip into the pot, the individual blank mould was lowered as it passed over the pot, much as a horse dips its nose into the watering trough.

During the past twenty years the Owens-type machine and process has been improved and many new models have been brought out. These include machines with multiple mould cavities and with multiple moulds in each section, so that as many as three bottles can be made by one mould and as many as six bottles by one section. Some of these machines have as much as fifteen sections or arms, giving a very much higher production, mostly of smaller bottles. The use of duplex mould cavities has been extended to larger and larger bottles and the efficiency of the machine has been increased. An improved model, particularly devoted to the making of different types of ware simultaneously, has also been brought out.

While the Owens bottle machine was being developed in the early days, various people were experimenting also with a pre-moulded blank for narrow-neck bottles and succeeded in producing various types of machines which could hardly be called even semi-automatic. As all the operations on them were by hand, they were simply mechanical aids to hand-operated moulding; but they had many of the features of the modern, gob-fed narrow-neck machine. In general these machines, of which there were several, had an inverted parison mould, with a neck ring held in tongs, and a plunger set up into the neck ring.

Glass was fed into this parison mould by hand and cut off by hand. Then the operator pulled down a blow-head and applied compressed air to pack the glass down into the mould, an operation now known as "settle blow." This compacted the glass around the plunger or neck pin, forming the preliminary blow opening. Then the blow-head was lifted, the plunger was pulled by a treadle and compressed air was introduced through the plunger opening, a baffle plate or bottom closure having been applied meanwhile in place of the blow-head to close the bottom of the mould. This blew a bubble into the neck of the parison and filled the mould cavity with glass at its upper end.

The parison mould was now opened, leaving the parison standing inverted in the neck ring. The neck ring was then lifted with tongs, turning the parison over right side up and placing it in the blow mould, after which the neck-ring halves were opened and the parison was left suspended in the mould. It was then blown by manipulating a blow-head by hand and the finished bottle was removed by hand.

The first machines had only one blank and one blow mould, but two blank moulds and two blow moulds were used subsequently. They never made ware of very good quality nor could they reach very high production, and they were strictly limited to hand feeding. The next step resulted in various attempts to apply rotating turrets to groups of such moulds, using the same hand transfer system and the same steps in forming. These had varying degrees of success, depending on the type of ware, as well as on the construction of the machine. The advent of automatic feeding gave momentum to the development of these machines, although they had to be adapted and correlated both in structure and cycle.

One of the early machines which was adapted to operate with automatic feeding was the O'Neill No. 25 machine, illustrated herewith. This machine had two turrets, side by side, one carrying six blank moulds and the other six blow moulds. The blank moulds were on turning heads for inversion and the turrets were indexed step by step in unison by an air cylinder, the auxiliary operations, such as table locking, unlocking, mould opening and closing, etc., being performed by properly timed air cylinders.

In the O'Neill cycle the blank mould was fed with glass and the charge was settled in by compressed air. The mould then moved to the next station, turning over to bring it right side up, and a bottom or baffle plate was applied, after which the counterblow took place completing the parison. The turret then advanced another

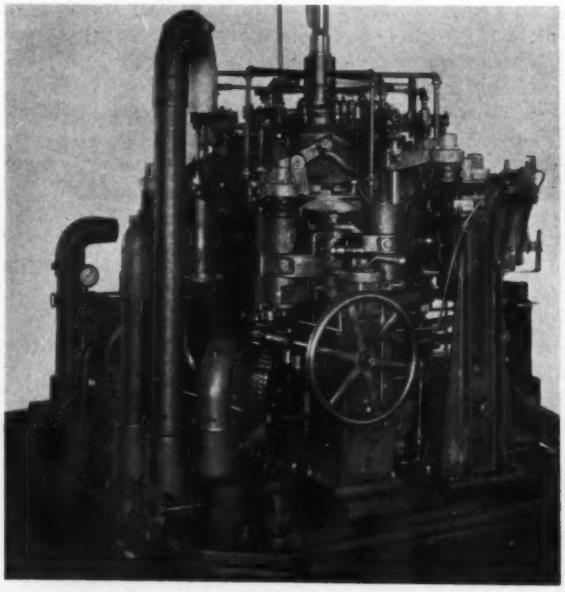


Fig. 7. Hartford-Empire No. 870 narrow-neck machine, driven throughout by mechanical motions instead of air cylinders. This machine had a single turret carrying both blank and blow moulds.

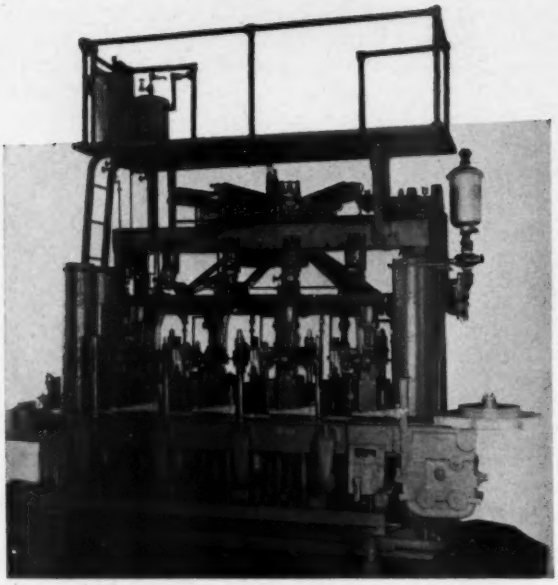


Fig. 8. Hartford-Empire I-S machine. Differs from previous narrow-neck machines in that moulds remain stationary and merely open and close. Has practically no limitations in cycle or speed, except those set by the glass itself.

step, to bring this mould to the transfer station where it was opened and a blow mould on the other turret closed about the suspended parison, which in some models was thrust radially over with the neck ring. As the blow mould closed, the neck ring opened and went back into position. In subsequent steps, the parison was blown at a blow station, the blow mould was opened, and the finished bottle was automatically removed by air-operated tongs and placed on a conveyor. It should be noted that this machine was sometimes fed by hand, but that it was primarily developed to meet the demands of automatic feeding.

Another narrow-neck, air-driven machine which went into extensive use about this time was the Lynch Model LA bottle machine which also had two turrets, with inverting heads for the parison moulds on one and blow moulds on the other. However, in this machine the blow-moulds and parison-moulds were mounted in holders, whereas in the O'Neill machine the moulds were in units very much like the old-time hand blow moulds. As in the O'Neill machine, this Lynch machine had its operations all automatic and actuated by air, the steps being similar except that the neck ring did not move radially during the transfer, but merely opened. There were other variations of this Lynch machine, one being especially designed for small bottles and another for large bottles.

The needs for greater production and for improved manufacturing cycles caused the Lynch Corporation to improve its older machines, the result being the Lynch No. 10 bottle machine, also shown herewith. In this machine various cycle limitations have been removed by providing blow heads and baffle plates which travel with the moulds and which, therefore, are not confined to operation at a particular station, thus making the machine more versatile and providing a more efficient cycle. Although this machine indexes its turrets by air cylinder step by step like the earlier ones, the operation is improved and much smoother. A greater reserve of force, both for rotating and cushioning, enables the turrets to step around at the much higher speeds permitted in the improved cycle.

Another type of machine which came into use about twenty years ago was the Hartford No. 870 narrow-neck machine, operated entirely by mechanical drives instead of by air. This machine was able to carry heavy moulds and to operate at good speeds, but was much more expensive than the air-driven machines. It was one of the first machines to remove cycle limitations, the blow-heads traveling with the moulds so that blowing could take place at any time.

All of the foregoing narrow-neck bottle machines had revolving turrets that carried the moulds, thereby introducing mechanical limitations and centrifugal force difficulties. This limited the size of the moulds that might be mounted for a particular bottle and limited production speed by inertia troubles. These limitations were overcome in the Hartford I-S machine by having the moulds remain stationary. The mould parts go through a cycle similar to those of the other machines, but the moulds simply open and close and do not change their positions. Therefore, the moulds may be made as heavy as desirable and the operating steps may take place at any desired time and as rapidly as needed. This permits a very efficient cycle and a much greater production per mould per minute.

In the I-S machine the blow mould is working most of the time and is idle very little. This is permitted not only by the possible sequence of steps, but also by the fact that the moulds may be made sufficiently heavy for rapid absorption of heat. Four moulds are enough for an average unit, although anywhere from two to eight sections can be employed. The sections are arranged side by side in a straight line, so that the bottles may be transferred automatically by a takeout to a conveyor which takes them up to the lehr in a row from the four different takeout stations. The mould charges are distributed to the blank moulds by a sliding trough system from the feeder. There is no inertia nor centrifugal force, before or after transfer, acting to distort the parison and spoil the distribution of the glass in the finished bottle.

The range of the I-S machine is from ware weighing about a quarter of an ounce to gallon packers of about 60 ounces. On the smallest ware it has been operated as fast as 72 per minute. This is a little unusual, however, and its regular range is from 65 per minute on fractional ounce bottles to 27 per minute on 13 ounce weight jars, or 20 per minute on 24½-ounce weight sodas. The machine can also make semi-wide and wide-mouth ware of various types, as well as narrow-neck ware.

Paste-Mould Machines

Twenty years ago the Empire Machine Company's Type E semi-automatic paste-mould machine had reached its prime. In its operation, glass was gathered by hand on a blow-pipe which was then inserted in the machine, and the machine then automatically marvered, puffed, swung and stretched the glass until the parison was fully developed, whereupon it was blown automatically in a paste mould. These machines included a number of individual sections on one base side by side, as shown in

the accompanying illustration. They were used mostly in the manufacture of bulbs for incandescent lamps.

The speed of a four-section machine was from 8 to 12 per minute, depending on the size of the bulb being made and the skill of the operator. This speed was about two or three times what a hand shop could accomplish without the machine. Some of these machines are still in use for thermos-bottle pistons, for special types of bulbs and for tumblers and beakers. It should be noted that this is one of the early examples of an individual section machine like the Hartford I-S machine.

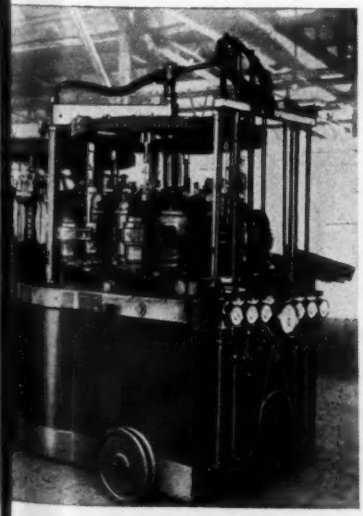
Another paste-mould machine of twenty years ago was the Westlake machine, at that time fully as large as a 10-arm Owens bottle machine. This machine was provided with a number of similar sections revolving around on a turret like the Owens machine. Each section had a gathering ram which paused before the gathering boot in the furnace, thrust into the furnace and gathered a blank by vacuum very much like the Owens machine, except that the blank was not a parison but merely a slug. When the ram came back to position over its section, it dropped out this slug on a blowing spindle where it was grasped by jaws. The spindle then put the blank through a series of motions and steps, very much like those used by a hand blower with a blowpipe, the blank being puffed, rotated, expanded and swung from an upward to a downward position. When the blank was properly elongated into a parison, after being swung by the spindle to a downwardly pointing position, a paste mould closed about the parison, and it was blown. When the mould opened, the jaws holding the article to the spindle opened and discharged the article upon a conveyor. All of this took place while the turret was revolving continuously around a vertical axis.

These Westlake machines were used for making all manner of paste-mould articles, such as incandescent lamp bulbs, thin-blown tumblers, parts of goblets, and lamp chimneys. First made with single spindles, they were later provided with double spindles, so as to produce twice as many articles with the same size of mechanism. A double-spindle, 12-section Westlake machine with 24 moulds could make 40-watt bulbs at the rate of about 60 per minute. Other articles could be made at proportionate speeds depending on size and type. General Electric Co. later built machines having four spindles in each section, and a total of 48 moulds. This again doubled the production of bulbs.

During the past twenty years these machines have been improved and redesigned in a much smaller and simpler form, so that they are now much smaller than the Owens machine and the mechanisms and motions have been considerably simplified. The Westlake machine was redesigned so as to accomodate 48 spindles. Another design made large-size bulbs up to PS-52. The principles have remained the same, however, the chief difference being found in the feeding, as only one ram is now used to feed the series of spindles instead of having a gathering ram traveling with each spindle.

About 1922 the Hartford-Empire Company took over the Type F paste-mould machine which had been developed up to this point by the Empire Machine Company. This was a machine of the press-and-blow type with an intermittently rotating turret and paste moulds. It was improved by Hartford and was used by the Corning Glass Works up to 1927 or 1928 for making bulbs and is still used in France for this purpose. After some work on improvement of the Type F machine, the Hartford organization began the development of a larger continuously rotating paste-mould machine of the press-and-blow type, now known as the Hartford-Empire No. 28 machine.

The No. 28 machine has 12 similar sections revolving continuously on a turret and, as each section passes a feeding station served by a gob feeder, a gob of glass is dropped into the press mould and pressed into a parison with a bead which is held by a neck ring. The blank mould drops away and the plunger rises clear, leaving



e Roirant A-6, used extensively abroad d to a limited extent in the United ates, operates on the intermittent suc- n principle, with a revolving pot built o the tank.

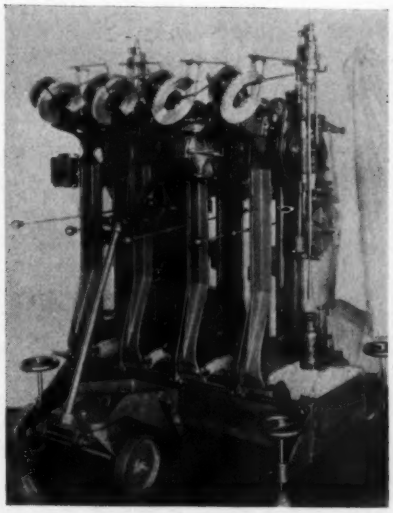


Fig. 10. A later model of the first paste-mould machine for making bulbs, developed originally by the Empire Machine Company. Reference to this machine appears on the preceding page.

Fig. 11. Westlake 12-section, double-spindle, paste-mould machine in operation. An improved design of the first successful completely automatic machine for paste-mould articles.

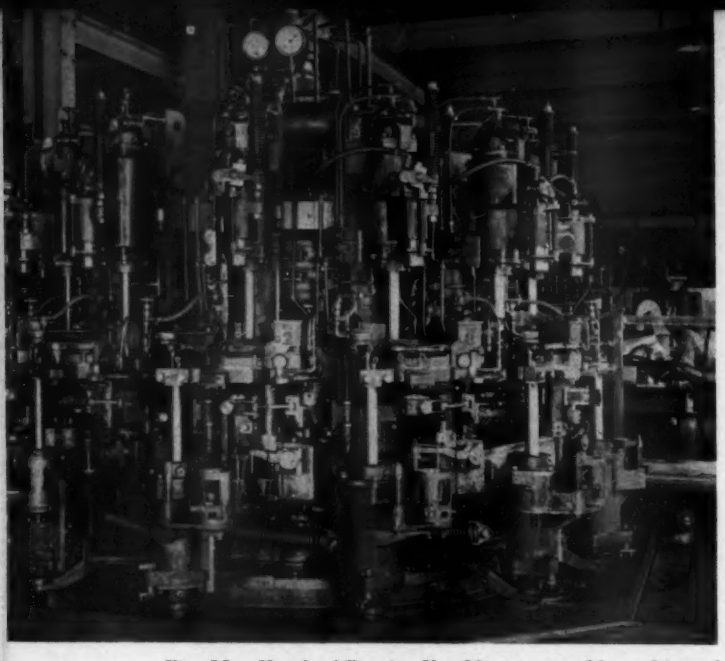


Fig. 12. Hartford-Empire No. 28 paste-mould machine of the press-and-blow type. An outgrowth of the Empire Type F machine, this model rotates continuously and is adapted for tumblers, lamp chimneys, beakers, etc.

the parison suspended in the neck ring where it is allowed to reheat and stretch and can also be puffed if desired. Then a paste mould comes up around the parison, which is revolving by this time, and the parison is blown into the finished article while it continues to revolve or oscillate. The blow-mould then drops away and the finished article is removed by a take-out device that places it on a conveyor running to the lehr.

The No. 28 machine differs from the Westlake type of rotary machine in that the parison or blank is always right side up, just as in a press-and-blow machine. It has a very considerable range of sizes and will make small or large tumblers or lamp chimneys. Tumblers of six-ounce capacity can be made at the rate of 55 per minute, smaller ware is made a little faster and larger ware a little slower. It is also adapted for bulbs, but is not fast enough to compete with the ribbon type of machine on standardized bulbs in quantity production.

A big advance in paste-mould machine development was achieved by Corning Glass Works in the evolution of the so-called "ribbon" machine, pictured in operation herewith. Here a steady stream of glass, discharging downwardly from an orifice, is rolled into a ribbon between two rollers which also shape it into alternate thick and thin portions, the thick portions being lens-shaped. This ribbon is then carried horizontally in a straight line by plates attached to a continuous chain, these plates having holes or orifices over which the thickened lens-shaped sections settle, the glass sagging down through the holes. Another chain located above the glass carries a series of blow-heads, which descend in succession over the holes, travel with them, and puff and help to stretch the sagging glass, forming parisons. A third chain beneath the glass carries a series of paste-moulds and these moulds close about the suspended parisons, rotating about their centers at the same time to give the usual paste-mould turning motion. The blow-heads blow the parisons into these moulds and, when blowing is completed, the moulds open and drop away around a sprocket, leaving the finished articles still connected to the parent ribbon and held by the plates. At the take-out station a plunger breaks off the article from the parent ribbon and sends it flying to a conveyor, the remains of the ribbon passing to cullet.

All of the chains in the ribbon machine travel continuously at considerable speed, the entire machine being arranged in a straight line leading away from the melting furnace and the discharge orifice. The finished articles are carried by a conveyor to an annealing lehr. The machine was developed primarily for lamp bulbs, which are manufactured on a large scale in a few standard sizes and, therefore, are suited to a machine with high productivity.

Although the ribbon machine was designed primarily for lamp bulbs, it has also been applied to the manufacture of bulbs for radio tubes, Christmas tree balls, and for certain standard sizes of thin-blown tumblers. The same principle has also been applied to the manufacture of glass articles on a smaller scale and in a similar smaller, lower-speed machine, known as the "Turret Chain" machine, which does not use a ribbon but merely flattened pats of glass which are deposited over holes in plates on a chain. This latter machine is applied primarily to tumblers and lamp chimneys.

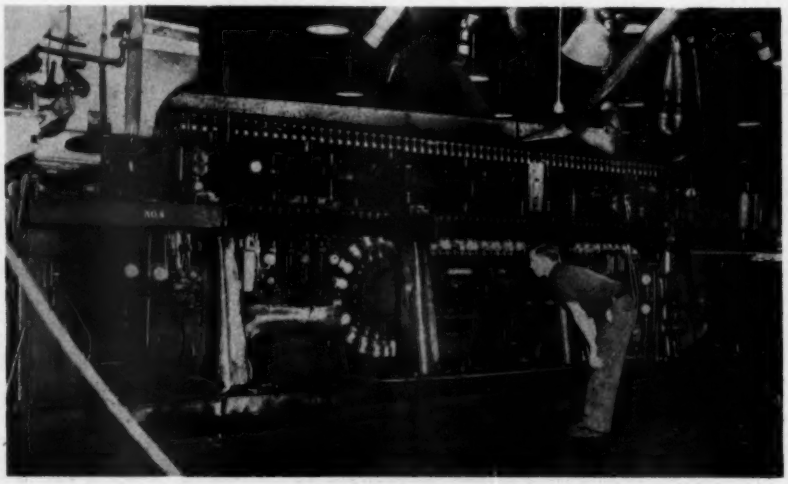


Fig. 13. Corning Glass Works' ribbon-type paste-mould machine, the fastest automatic machine for glassware ever built. Primarily adapted for manufacture of bulbs, its speed ranges from 400 to 600 and over per minute.

20 YEARS OF PROGRESS IN GLASS FORMING MACHINES. II

MACHINES FOR FLAT GLASS AND TUBING

By F. W. ADAMS, Mellon Institute

The last two decades have seen changes in the flat glass industry which have revolutionized the making of both plate and window glass. Older, partly-mechanized hand processes have been almost entirely replaced by highly-mechanized continuous processes.

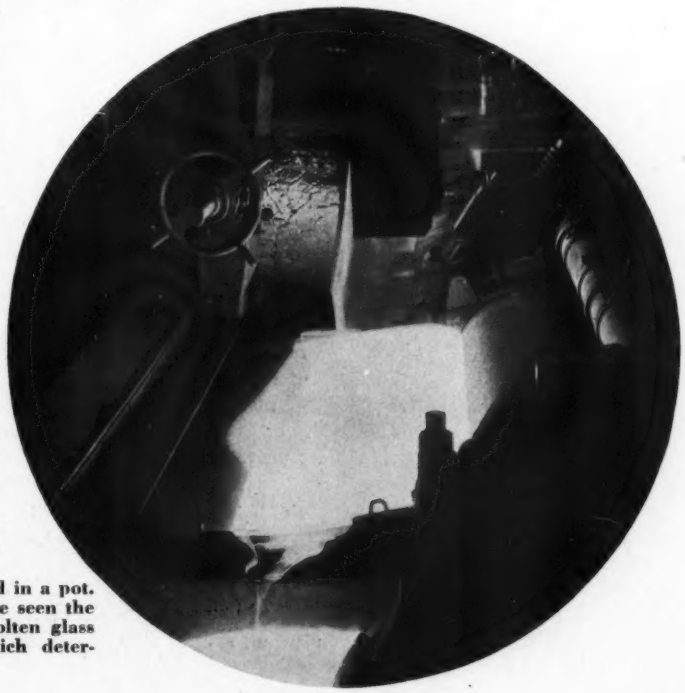
Previous to this period, plate glass was melted and refined entirely in pots which were handled out of the furnace by hand or by mechanically operated cranes. The plate was cast on a large, flat, castiron casting table about 16 feet wide and 30 feet long covered with fine sand to prevent sticking and chilling of the glass. The charge of molten glass was poured from the pot in a continuous stream ahead of a heavy cast-iron, water-cooled roller which, travelling along on iron tracks, rolled the glass out into a plate of uniform thickness. After passing over the molten glass the roller passed up onto wedges which raised it enough to permit the glass to be pushed from the table into the first of a series of five annealing ovens. Great skill and careful timing was required to coordinate the roll speed and rate of pouring, to the end that the plate of glass might be rolled smoothly and without ream or folds.

While the old casting method is used in isolated cases on special glasses, it has been almost entirely superseded by one of several continuous processes. Between 1922 and 1924 the Ford Motor Company and Pittsburgh Plate Glass Company each developed continuous automatic processes involving the formation of the rough rolled glass in a continuous ribbon. The glass batch is melted in a large continuous tank having a capacity of about 1000 tons, raw materials being pushed into one end of the furnace, melted and passed through the refining zone to the furnace outlet at the other end. Here the molten glass passes in a continuous stream through a wide refractory slot, down an incline onto a table of moving metal plates, where metal rollers squeeze the glass to a ribbon of uniform thickness. Alternatively, the glass may leave the furnace lip and pass directly between two water-cooled metal rollers, each approximately 12 inches in diameter. The red-hot ribbon of glass then passes over a horizontal series of rolls into the annealing lehr, where driven rolls carry it along and the temperature is reduced gradually over a length of several hundred feet. Emerging from the lehr the ribbon of rough glass is cut into sheets for transfer to the grinding and polishing machine.

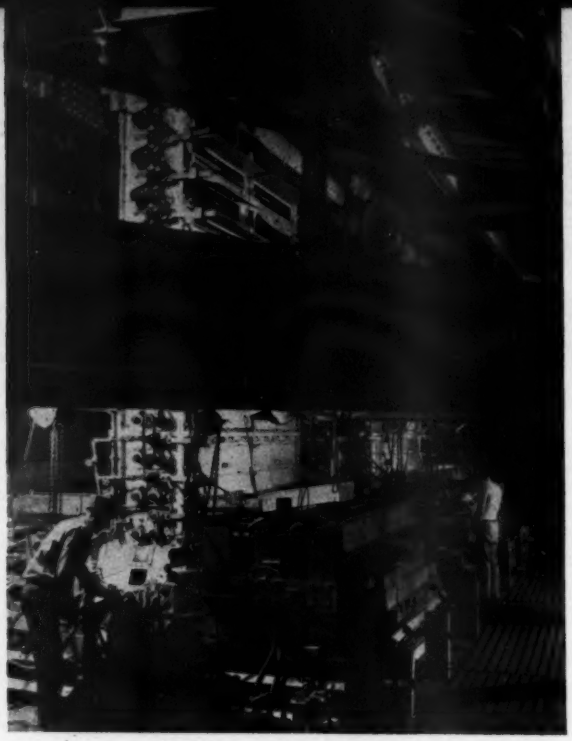
Another mechanical process for preparing a continuous ribbon of rough-rolled glass was developed by the Libbey Owens Sheet Glass Company about 1925. In this process molten glass from the tank flows into a shallow working compartment from which it is drawn upwards by two cooled iron rollers resting on the glass surface. The ribbon then passes over a horizontal roller where it is bent into the horizontal position and, supported by carrying rolls, enters the continuous lehr. As before, the sheet leaving the lehr is inspected and cut into sheets of suitable length for grinding and polishing.

The production capacity of these continuous processes is very large and particularly adapted to the production of glass with uniform thickness and of one composition, such as is used in the production of automobile glass. Short runs of plate glass or special flat glassses, such as the opaque glasses used in building construction, are more economically produced in pots and mechanically cast on machines particularly adapted to this need.

The Bicheroux process, developed in Germany shortly after the War, produces intermittently long sheets of glass rolled continuously from a single pot. The molten glass from the pot is first poured upon a tiltable trough or receiver from which the glass flows between two water-cooled iron rollers and downward over an inclined surface to a series of tables which travel forward to accommodate the entire sheet of glass. By means of rotating steel disks the ribbon is cut transversely to the length of an individual table and the tables are then moved rapidly to the annealing ovens from which the glass passes slowly through the annealing lehr.



Machine for rolling plate from glass melted in a pot. In this view of the casting operation can be seen the top of the large roller upon which the molten glass is poured and the superposed roller which determines the thickness of the rolled sheet.



The machine developed by the Pittsburgh Plate Glass Company for drawing sheet glass. The details of this machine are described in the accompanying text.

Another type of continuous casting equipment has been developed by Pittsburgh Plate Glass Company for rolling glass melted in pots. Here the molten glass is poured directly upon a large, hollow, heated roller approximately 12 feet in diameter, sufficiently large to take the entire contents of the pot. The molten glass feeds continuously between the large roller and a smaller roller above it, forming a ribbon of rough glass which goes directly into the annealing lehr.

Window Glass

Rapid strides have also been made in the window glass industry during this two-decade period. In the early twenties, hand production of window glass accounted for approximately one-third of the United States production; today manufacture is entirely by mechanical methods.

In the hand process, sufficient glass to produce a cylinder, from 15 to 20 inches in diameter by 50 to 70 inches long, was gathered by hand from the day tank on the end of a long blow-pipe. After suitable forming, the glass blower swung and blew this glass into a cylinder of relatively uniform wall thickness. After the ends were removed, the hollow cylinder was split and placed in the heating oven, where the glass softened and was flattened by a workman with a wooden tool or hoe. The glass was then passed through the annealing lehr and after cooling was cut into various sizes. This process was extremely ardous and even in 1920 was rapidly being superseded by machine-blown cylinder processes, such as the Lubbers process.

In the machine-blown cylinder process, molten glass was poured from a ladle into the drawing pot. By lowering a circular metal bait about ten inches in diameter on the end of a blow-pipe into the surface of the glass and withdrawing it slowly, it was found possible, using carefully controlled compressed air for blowing and an electrical hoist, to draw a continuous cylinder out of the kiln to a height of about 40 feet and approximately 30 inches in diameter. When the drawing of the cylinder was complete, it was removed from the blow-pipe and cut into shorter lengths that could be more easily handled. The cylinders were then split and flattened in the same manner as the old hand-blown cylinders. In some plants, glass from a continuous tank flowed into a number of individual drawing kilns, in which an annular firebrick block or "stone" floated on the surface of the glass and defined the diameter of the cylinder being drawn. The machine-blown cylinder process has since become obsolete, being entirely superseded by continuous sheet drawing processes, of which three deserve mention.

During 1917 the Libbey Owens Sheet Glass Company commenced drawing sheet glass by a continuous process in which glass is melted in a tank and feeds a battery of drawing kilns. Drawing is started by reversing the machinery and lowering a flat metal bait into the surface of the glass. As the surrounding glass is cooled it adheres to the bait and drawing is started. The glass is drawn vertically upward for about three feet and then passes over a horizontal roller which bends it into a horizontal plane. Here the edges are grasped by traveling belts and fed into the annealing lehr. Flat-tube water coolers adjacent to the glass meniscus chill the surfaces of the sheet to give it stability in the upward draw and suitable gas flames for maintaining the glass in a plastic condition play about the bending roller. Knurled fireclay rolls engage the edges of the sheet a few inches above the molten glass surface and form a thicker ribbon on each edge, thus maintaining sheet width and providing means for handling without damage to the sheet surface.

Just before the war in 1914, the Fourcault process was developed in Belgium for drawing sheet glass continuously and, following several successful installations in Europe after the war, this process was brought to the United States where it has since found considerable favor. In this process glass from a continuous tank flows into the kiln, where it is drawn vertically through a "debiteuse" by the drawing machine. The debiteuse consists of a refractory boat with a slot through the center through which the glass flows continously upward when the debiteuse is partly submerged. To start the drawing process a metal bait is lowered into the glass through the slot at the same time that the debiteuse is lowered and, as the glass starts flowing, the bait is slowly withdrawn with the adhering glass. Glass is continuously withdrawn in a ribbon form as fast as it flows up through the slot and is surface chilled by adjacent water coils. The ribbon passes up to asbestos-covered steel rollers which carry the ribbon vertically through a 25-foot annealing chimney or lehr. The glass emerges from this lehr upon the cutting platform, where sheets of suitable size are cut off and transferred to the glass cutter for grading and cutting.

Another important sheet glass development is the Pittsburgh Plate Glass Company process which draws glass continuously in a vertical machine. Molten glass is drawn from the surface of a pool by asbestos-covered rolls arranged vertically in the annealing lehr at sufficient distance from the hot part of the kiln to prevent surface marking. Thicker edges developed by driven knurled rolls near the meniscus maintain sheet width and provide bearing surfaces for the driving rolls. A submerged refractory draw-bar prevents the glass meniscus from

Continuous rolling machine for plate glass at the plant of the Ford Motor Company. This view shows the sheet leaving the rolling machine and entering the lehr.

wandering back and forth, and produces a symmetrically formed sheet. Water coolers on either side of the plastic glass film cool the surfaces sufficiently to harden the glass before it touches the first drawing roll. The glass continues to pass vertically through the lehr, in which it is supported every 12 inches by driven asbestos-covered rolls which deliver the ribbon to the cutting platform.

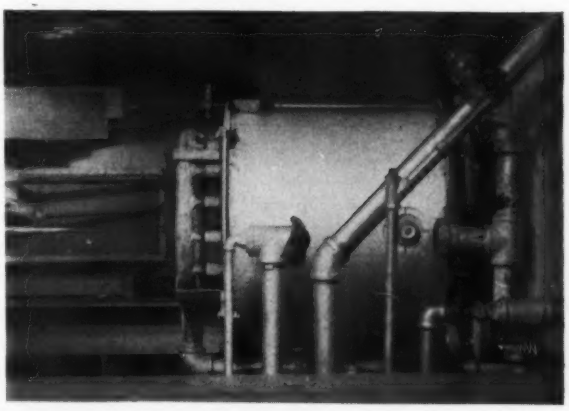
Glass Tubing and Rod

For many years glass tubing has been drawn by hand. This operation requires the services of two men, one of whom blows into the blow-pipe while his partner walks the length of the blowing floor with the gather of glass carried on a punty. For some requirements this operation has been replaced by an elevator which carries the glass up through a 60-foot tower while air pressure is maintained within the tubing. Both of these processes continue in use for certain types of glass; such as thermometer glass, and special types of tubing, or small orders.

Two continuous processes for drawing glass tubing in large quantities have been developed since the War and are now in general use. The Danner process was introduced into this country in the early twenties. In this machine, by means of a suitable level control and supply device, glass is fed continuously at a uniform rate from a pot or kiln upon an inclined rotating cylinder of refractory. A blow-pipe passing through the refractory maintains sufficient air pressure so that the glass being drawn from the lower end of this cylinder is evolved as a continuous tube. After passing through the air for ten or fifteen feet the tube is sufficiently cooled so that it may be handled upon rollers to the point where a belt drawing mechanism engages the tubing. Gripping the tubing both top and bottom, the drawing mechanism carries it forward through an annealing section to a cut-off saw where glass tubes of desired length are cut off and graded for diameter and wall thickness. Substitution of a solid rod for the blow-pipe permits drawing of rod or cane.

Very recent improvements in the Danner machine have given it still greater flexibility. A new feeding mechanism permits of increasing or decreasing the flow of glass in the forehearth which, coupled with an increase or decrease in the speed of the drawing mechanism, makes it possible to control and vary the rate of production within wide limits. Wall thickness of the tubing also can be varied so as to produce on the same mandrel tubing from ½ mm. thickness up to heavy capillary tubing.

The Vello process for making glass tubing and cane continuously operates on a radically different principle. By this process molten glass flows into a drawing compartment from which it drops vertically through an annular space surrounding a rotating rod or blow-pipe. Sufficient pressure is maintained through the blow-pipe to produce tubing of the diameter and wall thickness required. Rotation of the blow-pipe and synchronized rotation of the cooled tubing, which passes onto a horizontal conveyor, maintains even cooling as the vertical glass tubing turns the corner into a horizontal position.



Photograph of the Danner machine taken in the experimental laboratory at Newark, O., while the new feed-control mechanism was undergoing final tests in 1939.

Continuous sheet-glass drawing machine of the type developed by Libbey-Owens-Ford Glass Company.

20 YEARSOF PROGRESS IN GLASSWARE MOULDS

Glassware moulds are operated at much greater production rates today, in comparison with the moulds of 20 years ago and the total amount of ware produced by each mould during its operating life has been increased greatly. In fact, the performance of glass moulds has been so greatly improved during the past two decades that one involuntarily looks for some outstanding discovery or invention to account for the betterment. It is rather surprising to find, therefore, that there has been no such development and that the general improvement in the operating characteristics of glass moulds has resulted from almost continuous trial and testing of different materials, coupled with advances in the technique of mould manufacture in both foundry and machine shop.

Practically all glassware moulds of today are made of cast iron, just as they were 20 years ago. In those days moulds were made of the best available gray iron, cast against a chill, and it is of interest to note that the majority of moulds in use in 1940 are also made of the best available gray iron and likewise cast against a chill. In the interim there has been a great deal of activity in the development and use of alloy irons, this development reaching its peak some years ago. The swing back to plain, chill-cast iron moulds for general use began a few years ago, leaving the alloy irons for use to meet special operating requirements of temperature and pressure.

The present popularity of plain, chill-cast iron moulds is probably the result of two factors; first, economy, and second, the great improvement in available irons as a result of improved foundry practice. Foundrymen now produce, as a matter of course, glassware mould castings that are exceptionally homogeneous, free from hard spots, and well adapted for glassware forming. There are, of course, some requirements that can only be met by the utilization of alloy irons and such alloys include chromium, nickel, vanadium, molybdenum, copper, and aluminum. Chromium refines the grain, imparts hardness and resists growth and scaling; nickel reduces chill, increases hardness and strength and produces a close-grained iron; vanadium in small quantities hardens the metal and stabilizes the structure against heat; in small amounts molybdenum increases strength without hardness; copper, in proportions under 2 per cent, increases both strength and hardness and is used with molybdenum; aluminum increases strength and refines the grain but adds difficulties in the form of a frothy slag and blow holes.

The special alloy iron compositions are used for such parts as neck rings, liners, inserts, bottoms, and baffle plates. Plungers and moulds for pressed ware are often subjected to extremes of temperature and pressure and the alloy irons find a ready use for this type of mould. The alloy iron compositions usually possess high hardness, varying thermal expansions, different degrees of thermal conductivity and special degrees of resistance to heat and corrosion. It is possible by proper selection of desired characteristics to meet almost any special requirement.

It would seem that the development of materials for glassware moulds offers a fertile field for metallurgical research, but as a matter of fact such research is greatly handicapped by a lack of dependable and accurate operation data. During past years it has been necessary to sacrifice data on mould performance and to resort to any expedient to maintain production at the rate permitted by new feeders and forming machines. As a result, a great deal of the work on mould materials has been of an empirical nature and conclusions have been reached by cut-and-try methods. There are almost numberless variables in the mould problem, so it is not surprising that the same materials seem to give variable results or that there is such a wide difference of opinion regarding the value of certain mould iron compositions. Nevertheless, a great deal has been accomplished and the suppliers of metals and castings are able to offer dependable data on irons to meet specific conditions.

Some of the greatest advances in the production of glassware moulds have been made in the foundry and it is certain that the making of a good mould is impossible without proper foundry practice in the production of the casting. It has been learned that mould iron must receive an amount of care in the foundry that most irons do not need and this consideration has led to a specialization in glass mould materials by certain foundries. Space is not available here for detailed consideration of proper foundry practice, but it does involve proper selection of materials, including both scrap and pig; accurate control of cupola operation; painstaking care in the moulding and pouring; and, last but not least, the use of good pattern equipment.

Machine shop practice in the manufacture of glassware moulds is quite different from the practice of 20 years ago. At that time moulds were laboriously matched in sets; proper clearances were a matter of the skill of the mould maker; and cutting tools permitted the use of comparatively soft irons only. However, the rapid advance in glassware production rates, brought about by automatic feeders and forming machines, soon showed the inadequacy of the old-time mould shop and its product. In order to stand up under the new conditions, mould irons became denser and harder; finished moulds had to be completely interchangeable, both in the cavity and in the attachment means; and production of moulds had to be stepped up.

The problem of machining the dense chill-cast irons and the hard alloy irons has now been solved by the use of modern cutting tools, such as high-speed steel and tungsten carbide. Machining operations that would have been impossible 20 years ago are now accomplished rapidly and economically. The requisite interchangeability in mould cavities is secured by means of the modern types of duplicating machines, such as the Keller and the Gorton, which copy the contours of a master mould with extreme accuracy and are economical when a number of duplicate moulds are to be made.

Satisfactory accuracy in other parts of the mould is obtained by the use of modern jigs and fixtures, together with accurate micrometers and gauges. For lathe work some very useful and ingenious attachments have been developed to make the lot of the mould maker less diffi-

cult. Among these may be mentioned the magnetic profiler, especially advantageous for boring cavities in round moulds, and an attachment for turning geometrical designs. Other new machine tools, such as shapers, milling machines, etc., have also been added to the modern mould shop, until the production of accurately, highly-finished moulds, made from proper materials, has been reduced to an economical, commercial type of manufacturing. Modern mould manufacture has been freed largely from the personal idiosyncracies of the old-time mould maker of 20 years ago, although much hand work with file and chisel is still necessary for some complicated designs.

The design of a mould for a certain piece of glassware is more or less an independent problem in itself. The problem is difficult, too, since it involves such variables as glass weight, production rate, type of machine, etc. The designer must also keep in mind the limitations of mould shop operations and the machining cost. On new work it is sometimes necessary to change the design after a test in actual operation on the machine. The new developments in types of ware during the past two decades do not seem to have affected the fundamentals of mould design and manufacture to any great extent, the regular methods being adequate so far to cope with the glassware requirements.

An accomplishment of recent years which seems to have definite possibilities in glass mould production is the casting of the mould surface closely to size, so that the only finishing necessary is polishing. Such moulds are now produced by various foundries in considerable quantities. A similar type of the preformed mould surface is also being produced by the electro-deposition of iron on a master form. This latter method has not yet been used to any extent in glass plants, but considerable development work is in progress.

In the field of glassware mould maintenance an outstanding development is the use of modern welding equipment to repair cracked, checked and worn moulds. This equipment seems to be the "putting-on" tool for which the old-time mould makers longed. It has to be used by someone with skill and knowledge of mould materials, but the results are very much worth while. Outside of this development, mould maintenance still is a matter of hand cleaning and polishing.

Paste moulds for thin blown ware have not changed to any extent from those of years ago. The mould coating is still made with a carbonaceous material and a binder and the technique of baking and maintenance has not changed appreciably.

LOWELL C. HEWITT A MODERN PIONEER

Lowell C. Hewitt is director of research at the Laclede-Christy Clay Products Co., also holder of the company's fellowship at the Mellon Institute.

Mr. Hewitt has been engaged for some twenty years in the development of refractories. During that time he brought about many notable achievements that have increased the efficiency of furnace operations in a variety of industries, including Glass. Improvements relate to furnace lining materials, which not only give longer life but also permit higher operating temperatures. Mr. Hewitt is the author of numerous papers relating to the refractory industry.

C. W. PARMELEE'S BOOK PLACED IN CRYPT

"Clays and Some Other Ceramic Materials," by Professor C. W. Parmelee, Head of Department of Ceramic Engineering, University of Illinois, has been selected as one of the books for inclusion in the Crypt of Civilization at Oglethorpe University in Atlanta, Georgia. The Crypt has been prepared under the guidance and advice of some of the greatest scientists of this time and will contain the world's most authentic sources of knowledge contained in books. The Crypt will be sealed in May, 1940, and will remain inviolate until the year 8113 A.D. when the civilization of that century will view a cross-sectional view of the entire life of our world today.

FORTER-TEICHMANN IN LARGER QUARTERS

Need for enlarged office space to accommodate their rapidly expanding business has compelled the Forter-Teichmann Company to take additional space in the Martin Building, Pittsburgh, where the company's general offices are located. The company hereafter will be located at Room 509 instead of Room 523.

● William B. Lawson, formerly of The Harshaw Chemical Company and The International Nickel Company, announced the formation of W. B. Lawson, Inc., dealing in industrial chemicals, oils, and non-ferrous metals. Offices are in the Union Commerce Building, Cleveland.

NOT FATAL TO EAT GLASS

The eating of glass, although probably causing immediate injury to most persons, may or may not be fatal, states The Journal of the American Medical Association.

"The nature and extent of the harm done, if any," *The Journal* points out, "depends on the size, shape and number of particles ingested and on the presence or absence of food in the mouth with the glass or in the gastrointestinal tract at the time the glass is swallowed.

"The danger lies in perforation of the wall of the stomach or the intestine. It would hardly be safe to say that the average person can chew up and swallow glass without suffering immediate injury, but it seems to be beyond question that some persons can do so.

"Dr. Walter S. Haines reported a case in which 'a professional glass eater,' in the presence of Dr. Haines and Dr. E. F. Ingals, ate half a dozen 6 inch test tubes, two good sized lamp chimneys, an ordinary 4 ounce medicine bottle, two pieces of window glass, each 4 inches square, and three slips of colored glass each 1 inch wide and 3 inches long, biting the glass off the pieces offered him, chewing it up, and swallowing it much as if it had been an ordinary article of food. The glass eater had eaten a hearty meal before submitting to the test, as was his custom before each exhibition.

"He was kept under observation for several hours after eating the articles named but at no time did he show any unfavorable symptoms. He died, however, two or three years later, from a subacute gastroenteritis, presumably, Dr. Haines says, from the irritation produced by his long continued glass eating."

● FOR SALE: Two Model "M" Edward Miller 8-mould press and blow machines. These machines are in excellent mechanical condition and will be sold at a reasonable price. Address, Box 35, The Glass Industry.

20 YEARS OF PROGRESS IN ANNEALING

By C. CONE

Before reviewing progress in the development of such an essential procedure in glass manufacture, it is well to define the process of annealing as generally understood today. Briefly, the annealing of glass involves the following steps: (1) Holding a mass of glass above a critical minimum temperature long enough to reduce internal strain by plastic flow to less than a desired maximum value; then (2) cooling the mass to room temperature on a schedule that holds the strains, introduced by temperature differences resulting from cooling, below the same maximum value.

Glass has been manufactured, and annealed after a fashion, for more than 2,000 years, but important progress in the art and means of annealing seems to have been confined to the last hundred years or so. In the earliest days annealing was accomplished by such methods as allowing the glass to cool in the open air, perhaps near to the melting fires. Other methods consisted in burying the glass in hot sand, wood ashes or similar material, or in retarding the cooling of the glass by placing it, after forming, in an enclosed chamber above the melting retort. In the latter procedure is found the beginning of production methods.

Kiln annealing was also an important development, in which a separate refractory enclosure was preheated by fires of wood or coal to a temperature below the softening point of glass. Glassware was stacked in the enclosure as made, the fires being maintained meanwhile to hold temperature. When the space was filled, all openings were sealed and the whole mass was allowed to cool at its natural rate. A later refinement provided a muffle to enclose the glass ware, thus reducing the "bloom" caused by the action of the high-sulphur flue gases on the soda of the glass and improving temperature uniformity. Modifications of the kiln method are still used today for small scale production of certain heavy glass articles.

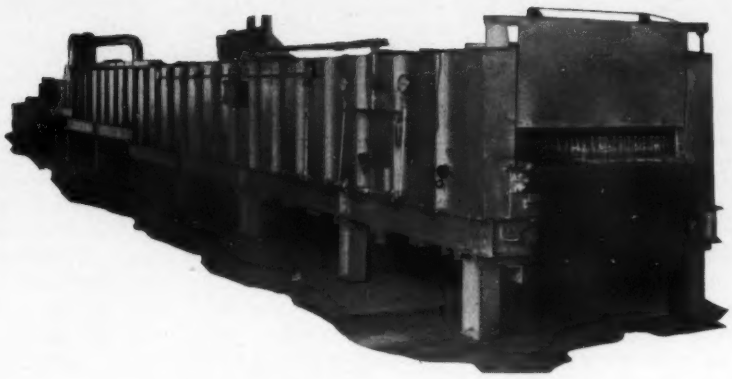
The introduction of labor-saving methods and mechanical equipment for glass working stimulated a parallel development in annealing methods and equipment. It was clearly uneconomical to heat and cool a heavy refractory structure, such as a kiln involving tons of brickwork, simply to obtain a controlled temperature drop in a few pounds of glass. The obvious remedy was to construct a long refractory tunnel heated at one end, with a gradual temperature drop toward the other, and by some means to move the glassware through the tunnel in the direction of the falling temperature. Earliest examples were heated by an open fire at the charging end and the temperature curve was controlled by drawing the flue gases through the tunnel to a stack located from one-half to two-thirds of the way toward the discharge end. The ware was carried on interlocking flat steel pans which were pulled out, one at a time, by a manually-operated winch and chain mechanism at the discharge end. The pans were then carried back to the loading end and hooked into position for another trip through the tunnel.

While annealing practice was gradually being improved, ideas as to what actually happened inside the mass of glass during the annealing operation apparently made little progress. Some very good annealing had been accomplished by cut-and-try methods, but there was still no way to predict what a new shape or composition of glass, or a new type of annealing curve, would involve.

When World War I began in 1914, virtually no high-quality optical glass was manufactured in this country and threatened curtailment of imports from Germany stimulated several glass manufacturers to attempt independent production of optical glass. At the same time, the Bureau of Standards was working with another manufacturer toward the same end. Progress was slow, however, and when we entered the war the problem of securing optical glass for ordnance requirements was acute. In the early part of 1917, a group of scientists from the Geophysical Laboratory was placed in charge of research on optical glass production in a number of the available glass plants and, for the first time, cooperation in the solution of a common problem entered the picture.

The pioneering work on annealing theory grew out of this situation and a paper entitled "The Annealing of Glass," by L. H. Adams and E. D. Williamson of the Geophysical Laboratory, was published in November, 1920, covering the subject very comprehensively. It still represents one of the most valuable references on the subject. With the formulae set up by these investigators and with some laboratory test data on the physical properties of the glass to be annealed, it is possible to compute an ideal annealing curve for any simple shape

The two annealing lehrs shown in this picture have about the same capacity, the one at the left being of the oil-fired muffle type with brickwork casing. The lehr at the right is a more modern type with an insulated steel housing and continuous wire-mesh conveyor belt.



Modern continuous, gas-fired annealing lehr for containers, showing the charging end. The annealing zone is fully insulated and heated by direct-firing burners below the wire-mesh conveyor belt. The cooling zone at the far end is largely uninsulated, additional cooling being supplied by air from a fan. Photo courtesy of Hartford-Empire Co.

and for glass of any composition, to give a predetermined residual stress after cooling to room temperature. It is also possible to predict the temporary stresses acting on the glass at any stage of the time-temperature cycle.

The work of Adams and Williamson dealt primarily with optical glass and made possible great savings in the time required to anneal these heavy sections to the fine degree required in optical work. For application to the annealing of more complex shapes under commercial production conditions, however, it has been necessary to use a modification of the ideal method arranged to take care of operating variables encountered in this class of work and to reduce temporary cooling stresses somewhat below those allowable with simple shapes. Nevertheless, we now know what we are trying to do when we start out to anneal a piece of glass and therefore we are able to figure out the best way of doing it. Perhaps the highest achievement in theoretical annealing is represented by the results secured on the two 200-in. reflectors cast at Corning Glass Works.

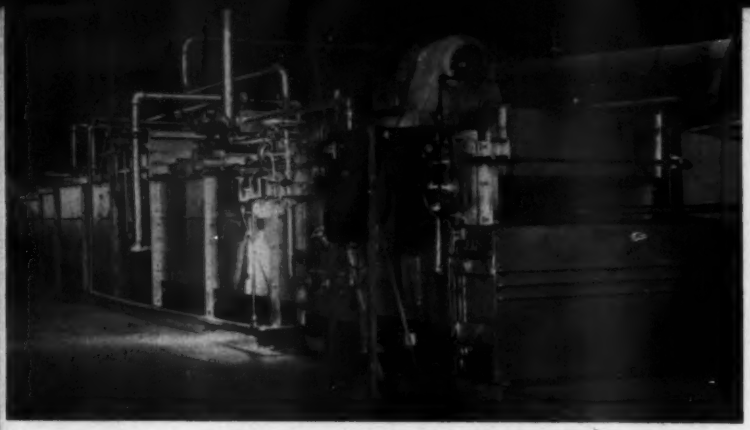
The lehrs in use today are almost entirely a development of the present generation. Designs have been continually improved to control the quality and uniformity of annealing, while reducing to a minimum the cost of investment, fuel, labor and repairs. And to a considerable extent, developments in lehr design represent the application of developments in parallel fields of industrial furnace work. Considering first the unit lehr for annealing bottles, tableware, and similar glass articles, the more important developments concern the conveyor, the enclosure, automatic temperature control, and the heating equipment.

Because the conveyor for transporting glassware through the heating tunnel must necessarily go through the same temperature cycle as the glass and therefore, must be reheated on each trip through the lehr. any weight saved in the construction of this part represents a saving in fuel. The earlier power-driven conveyors, constructed of steel channel sections, represented little progress in this direction over the hand-pulled units. The introduction of woven-wire conveyor belts was a big step forward. Subsequent development has been in the improvement of belt construction, together with the supporting and guiding means, in order to permit further saving by reduction of belt weight without sacrificing belt life. Efforts have also been made to eliminate entirely the item of fuel for heating the conveyor by using a special type of mechanism, such as a series of driven rollers which does not move bodily through the tunnel. In general, the saving of fuel in this design does not seem to offset the increased cost and complexity of the mechanism.

Improvements in the structure of the lehr tunnel include the provision of a rigid, structural-steel casing to cut down air infiltration and protect the refractory work; the use of insulating materials in the lining to save fuel and improve temperature uniformity in the cross-section; and improvements in roof suspension and insulation. The result has been a lehr tunnel structure requiring practically no maintenance in ordinary operation.

The modern annealing unit has been made an almost completely automatic machine by taking advantage of the latest developments in temperature control equipment. Although a single temperature control unit seems to be adequate for many lehr installations, multiple control can also be used under more exacting requirements to maintain a constant temperature curve throughout the length of the tunnel. The success of automatic temperature control on lehr applications is largely tied up with improvements in heating systems.

Accompanying the introduction of power-driven conveyors, a notable improvement in the open-fired, pan-type lehr was the provision of a refractory muffle to confine and direct combustion and to keep flue gases away from the glass. This construction eliminated most



Special continuous lehr which can be used either for annealing or decorating, as desired. The annealing zone is heated by transverse burners beneath the conveyor and has a recirculating fan for the products of combustion. The decorating section is located near the center of the lehr and is heated by radiant tubes. Photo courtesy of Surface Combustion Co.

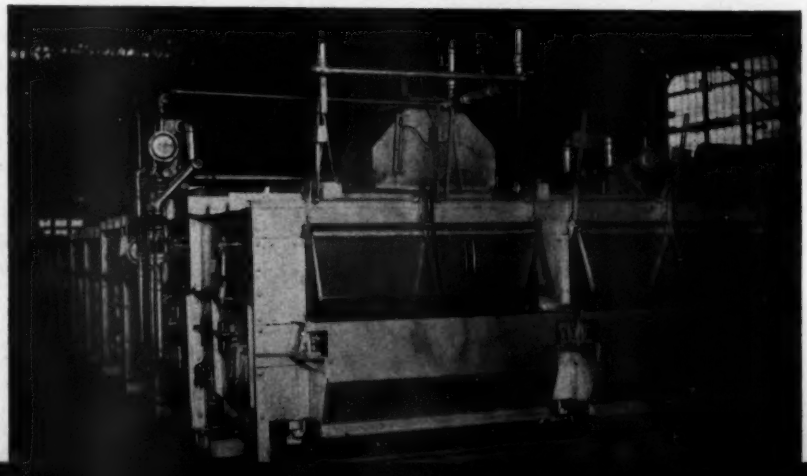
of the "bloom" previously encountered with high-sulphur fuels and also gave improved control over the constancy of the temperature curve. However, in the growing number of lehrs fired with clean fuel gas, the protection of the muffle was unnecessary and it was also realized that the muffle introduced an undesirable element in the application of automatic temperature control, because of the time lag between a change of fuel input and the response of the thermocouple. Present developments are in the direction of open firing, with velocity or fan recirculation with natural or clean city gas fuel, or the use of light heat-resisting alloy muffles of low temperature lag. A number of electrically-heated lehrs have been installed, but in view of current developments in the application of gas fuels, when available, the considerably higher cost of electric heat is in most cases difficult to justify at present.

Parallel with the development of unit lehrs, there was also a notable improvement in the technique of annealing flat glass, including sheet or window glass and plate glass blanks. Annealing of these products is now on a new level of uniformity and quality and the annealing time required for securing these fine results is in many cases about half that required a few years ago for inferior treatment. The annealing of flat glass in continuous strips is complicated by the fact that residual strain results not only from the cooling rate through the critical zone which determines strain distribution through the thickness of the glass, but also from lateral temperature distribution in the same interval which governs value and direction of strain between the edges and center of the strip.

The decorating of glassware, insofar as it involves the firing or ceramic colors on the surface of glass, calls for a second annealing operation, usually accomplished in a special lehr. In the decorating field, continuous lehrs have largely replaced the muffle kilns formerly used. Developments in decorating lehrs have closely paralleled those in annealing lehrs, but the special problems of the decorating operation have received increasing attention. Recent developments in methods of gas firing to produce concentrated radiant heat under accurate control, similar to that given by electrical heating elements, have made possible new standards of quality in decorated ware. Within the past year, an investigation has been made of the factors governing the shape of the heating-up curve from the charge end to the point of maximum temperature, thus giving a basis for designing this end of the lehr as scientifically as the annealing zone. Continual improvement in designs for decorating lehrs has also been necessary to keep pace with the rapid developments in ceramic colors that resist acid and alkali attacks and require higher temperatures and improved control.

There still remains a small classification of annealing and decorating operations, principally concerned with limited production of heavy or special ware for which an oven type of lehr is more economical than a conveyor unit. For these requirements there has been developed an efficient, gas-fired recirculating oven, well insulated with a lining of low heat capacity, with which it is possible to duplicate the best results secured in continuous lehrs with smaller fuel consumption and shorter time cycles than were required by the old kiln unit. For larger prodution the continuous lehr, however, is almost always preferred. Conveyor type lehrs are now operating with time cycles, from end to end of tunnel, ranging from three minutes to 48 hours, under accurate control and annealing everything from light bulbs to heavy optical glass blanks.

Current developments in glass technology promise to affect the annealing picture of the future. There is a growing list of articles made of glass which reach the market with a high degree of carefully established strain. At the present time, an annealing operation is involved in the manufacture of most of these articles, the desired hardening or toughening strain being introduced in a subsequent heat-treating operation. How far this technique of pre-stressing glass to resist better the stresses of later service may affect the future of annealing is difficult to predict. It is known that a similar stress distribution may be obtained, to a certain extent, by annealing glass after a surface treatment in a special atmosphere. The latter process has attractive possibilities, especially for containers and hollow ware which cannot be toughened by present methods of heat treatment.



Special double-belt lehr in which either side can be operated at any desired speed and temperature independent of the other. Common recirculating fan serves both sides of the lehr and independent sets of automatic proportioning gas burners are provided for the two heating zones. Photo courtesy of Surface Combustion Co.

NEW USES FOR GLASS

By S. R. SCHOLES
Alfred University, Alfred, N. Y.

To set forth the extension in the uses for glass during the past two decades, without confusing new uses with new methods of production of wares for old uses, is a difficult task and this review will probably fail to draw rigid lines of separation. However, many of the newer wares, because of their improved adaptation to old purposes, differ so much from corresponding glass articles made in the 'teens that they really constitute new products.

Glass has two important properties, upon which are founded its indispensability as a material of civilization. It is transparent and it is chemically resistant. The transparency can be varied by the addition of oxides or elements exercising selective absorption and thereby producing colors or changing the character of visible light or radiant energy transmitted. Also, the optical characteristics allied to transparency, such as refracting and dispensing power, can be controlled over wide ranges. Chemical resistance, likewise, can be made so slight that the glass is water-soluble; it can be adequate for the windows and bottles of commerce; or it can be great enough to satisfy the critical demands of modern chemistry and pharmacy.

Whatever has been done in recent years to extend the usefulness of glass has depended largely on the increasing ability of technologists to vary and control these two essential properties. But the supreme ductility of glass, in its swift and smooth transition from fluidity to rigidity, has laid hold of the imaginations of countless inventors and designers. This easy workability has called forth its share of the new applications of the versatile stuff.

New Developments in Flat Glass

A review of the items of glassware that have been developed during the past twenty years arranges itself naturally according to the major fields of glass manufacture. Glass for windows was ready when the motor age arrived and the closed automobile created and satisfied a new desire. For some years, ordinary plate or even window glass sufficed to stop the wind and dust and admit light. The element of safety was at first neglected. The great advance came when transparent plastics were ready to be inserted as a "sandwich" layer between two panes of glass, and to adhere firmly. Not only are such windows less easily smashed, but fragments and splinters are firmly held by the adherent, flexible, plastic layer, and injuries from flying glass are almost completely matters of regrettable history.

Very lately, the insistent demands of plate-glass manufacturers upon the makers of plastics have resulted in the synthesis of a product that seems ideal in its permanence against light, endurance of high and low temperatures, adherence, flexibility, and most important, strength. All these facts are matters of common knowledge. The advance has gone step-by-step with the needs of car manufacturers, the demands of the public for greater safety, and the requirements of legislation. It is a fine example of cooperation between independent, competitive fields of technology.

The modern glass window does more than stop a windhole. By the use of selected, pure materials, the glassmaker produces plate and window glass that is practically colorless and that transmits not only almost all the light of the visible spectrum, but also admits much more active or near-ultra-violet than did our fathers' windows. Working for a different purpose, the glassmaker loads his glass with ferrous iron, and without giving it unpleasant color makes it stop radiant heat from entering or leaving a building.

Glass bottles and containers now do more than merely contain. They are designed to display contents and attract buyers; they are shaped to pack conveniently for shipment and use; and they are light in weight, so that freight charges are lessened. All these advantages have been made possible by the perfection, or so we now think, of automatic manufacture. Tumblers, machine-pressed or pressed-blown, need no longer be the clumsy things of the last generation, but instead they have a lightness and general excellence that has made them the equal in most respects of hand-and-mouth blown ware.

Fiber Glass and Its Uses

Threads, fibers, and wool made from hot glass have been known for many years, but it remained for this period to bring about the development of a glass fiber that could be spun into yarn, made into thread, and woven into a successful new fabric. The two characteristics, of great strength and high resistance against corrosion of all sorts, make it certain that glass textiles in various forms will find an ever-increasing list of uses.

When glass is steam-blown into even finer, inter-curled filaments as glass wool, it forms a sister product that arrives just in time to give the new industry of air-conditioning just the sort of insulating material needed—moisture-, heat-, and vermin-proof. Glass wool of a sort had been made previously, but the field of usefulness opening before the modern product, in its uniformity, quantity, and durable excellence, far exceeds any expectations current in 1920.

Resistance to chemical reagents is no new attribute of glass, but the beakers, flasks, and tubes of the laboratory now have their industrial counterparts in glass equipment for manufacturing processes. The use of resistant boro-silicate glass for centrifugal pumps marks a new choice of an engineering material. Pipe lines of glass tubing, with large diameters and flanged couplings and capable of conveying corrosive acids safely and visibly, constitute another remarkable achievement and a boon to the industrial chemist.

Architectural Glass

In building construction, the glass block is winning its way, providing walls and partitions that beautify both

(*Continued on page* 201)

WORLD TRADE IN GLASS 1920-1938

By EDWARD J. DETGEN
Assistant Chief, Specialties Division
Bureau of Foreign and Domestic Commerce

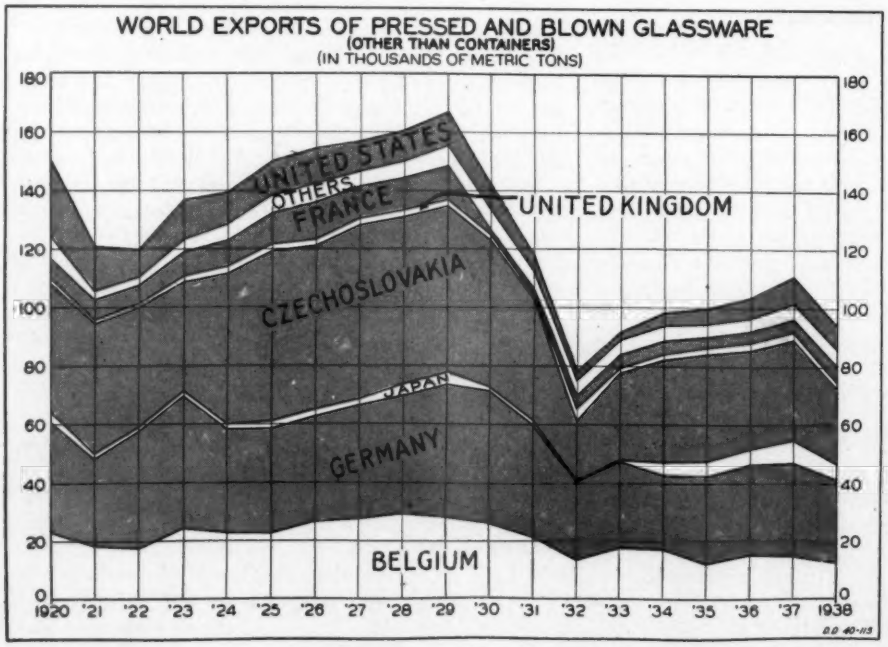
Like bread and milk, glass is, in most instances, a local affair. About 90 per cent of the world's production never crosses a frontier, but the remaining 10 per cent plays an important role in the world's economy, weaving a trade pattern of unusual design. Although glass products are manufactured in many countries in the world, most of the export of these articles is carried on by a few major suppliers. Over a period of years the important suppliers to foreign markets have been Belgium, Germany, Japan, Czecho-Slovakia, the United Kingdom, France, the Netherlands, the United States and, in recent years, Italy and Sweden. This is the group of countries with which we will be concerned in discussing the world trade situation during the past 20 years. Obviously, it will be necessary to limit the discussion to the more important developments.

At the outset it should be understood that covering a 20-year period in the international glass trade is a difficult assignment from the statistical angle. Comparisons cannot be made on a value basis, since foreign exchange fluctuations, currency devaluations and similar developments make a common denominator practically impossible. On the other hand, quantity figures vary according to the country of origin and the type of glass, so that conversions must be made regardless. For the purposes of this survey, it was decided to use the metric ton as the basis of comparison, so that all statistics have been computed or estimated in that unit.

So that we may have some idea of the value of this industry and trade, an estimate of one year's operations has been prepared. This reveals that the world's annual production approximates $800,000,000, of which about $125,000,000 is exported. It should be noted that while, on a quantity basis, only 10 per cent passes through foreign trade channels, on a value basis more than 15 per cent of the total is involved.

By 1920 most of the glass industries throughout the world had resumed operations which had been suspended by the War. Although the world trade picture of that year reveals some evidence of war-time dislocation, for the most part exports were passing through pre-war channels. Belgium had resumed her leading position, accounting for 27 per cent of the total world exports, while Germany and Czecho-Slovakia combined shipped 28 per cent. (Prior to the War most of the Czech trade was of German origin.) The United States was still holding on to its War markets with shipments totaling 141,200 metric tons (16 per cent of the total). France, the United Kingdom, the Netherlands, Japan, Sweden and Italy followed in that order to make up the estimated trade volume of 875,000 metric tons.

Following general business trends, world glass exports dropped sharply in 1921 to 628,000 tons, but rose almost continuously after that to the 1929 all-time peak of 1,155,000 metric tons. In the course of these years Belgium captured additional markets, increasing her share to 35 per cent, Czecho-Slovakian exports expanded to 222,800 tons (19 per cent of the total), and French exports increased to almost 175,000 tons (15 per cent of the total). Germany about held her own, but the United States, despite increased sales, was supplying only 5 per cent of the world market. During this period the Nether-



The area between the base and the top horizontal line indicates the total world trade by years in pressed and blown ware. Each individual horizontal band represents the proportionate share each nation has enjoyed of the total. The charts on the succeeding pages should be read in similar manner.

lands obtained decreasing amounts of foreign business and declined to a 3 per cent participation.

Exports dropped again in the depression years, falling as low as 551,000 tons in 1932. At that time Belgium still held her leading position, but her share had been decreased to 29 per cent. Czecho-Slovakia was second with 21 per cent and Germany third with 18 per cent. France had lost ground slightly, dropping to 9 per cent, the United Kingdom held firm at 7 per cent, and the United States was down to 4 per cent. A significant development of this period was the increase in Japan's glass trade despite the downward trend in other countries. Her share of the world market had risen to 8 per cent by 1932.

During the 1932-1938 period some recovery was made by the glass trade—the highest point being 1937—when exports totaled 788,600 metric tons. Belgium continued her leading role, but obtained only 24 per cent of the total trade, Germany rose to second place with her normal 18 per cent, and Czecho-Slovakia barely held third position with 16 per cent. Japan by this time had made deep inroads in the world glass market and rose to fourth place with 14 per cent of the total. The United States also moved forward, obtaining 7 per cent of the trade which ranked her in fifth place. The United Kingdom was sixth with 6 per cent, and France followed, continuing her decline to a 5 per cent share. By 1937 the Netherlands was supplying less than 1 per cent of the export market; on the other hand, Sweden had become a factor and Italy was beginning to obtain sizable foreign orders. This was the approximate situation when the European war broke out in the fall of 1939.

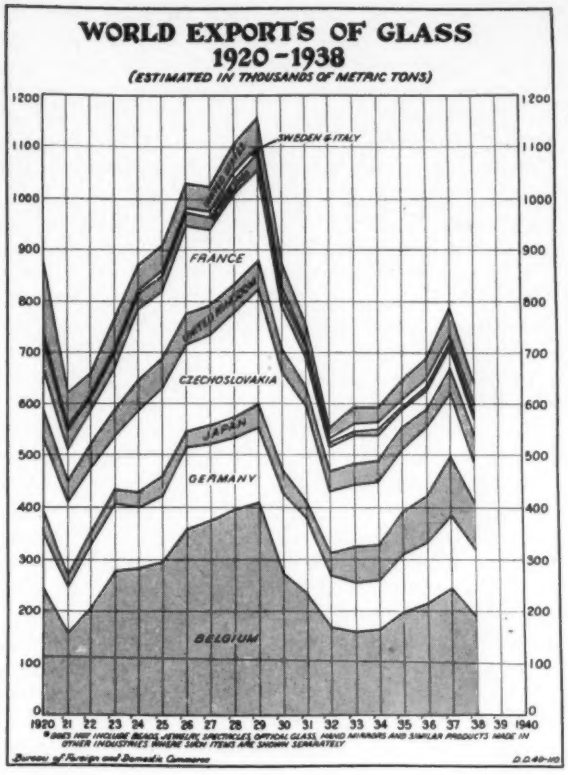


Plate Glass

World exports of plate glass have followed the general glass trend since 1920, except that they experienced a high point in 1926 not reflected by over-all totals. Belgium has been the leading supplier, followed by Germany, the United Kingdom, Czecho-Slovakia and the United States in that order. During the 1925-1929 period France and the Netherlands were important factors in this trade, but otherwise they have played a minor role. Italy, Japan and Sweden have never been exporters of plate glass in any quantities, although the Japanese obtained some foreign business in 1937 and 1938 and appear to be entering this field.

Belgian exports of plate glass during 1920 totaled 40,000 tons and dropped in the following year to 24,500 tons—the low point of the 1920-1938 period. This trade rose to as high as 79,900 tons in 1928 but was down to 28,800 tons in 1938. Belgian plate glass is shipped to practically every world market, but over a period of years the bulk of this trade has been with a relatively few countries. The United Kingdom was Belgium's leading plate glass market in 1920; France, Italy, the United States and Canada followed in that order. By 1929 the United States had become her most important outlet, while Argentina (which ranked sixth in 1920) was second in importance. The United Kingdom, Canada, Australia and Japan were also important consumers of Belgian plate glass in 1929. Recently (1937), the United Kingdom has returned to her former leading position as Belgium's most important market, and Australia has become second in rank; the United States has dropped to third place followed by Argentina, Canada and France.

German exports of plate glass amounted to 17,600 tons in 1920, declined to 7,400 tons by 1923, rose to 25,900 tons in 1926, dropped again to 11,700 tons by 1934 and were slightly below this level in 1938. In 1920 the Netherlands was Germany's leading plate glass market. Switzerland ranked second, France third, Italy fourth, Denmark fifth, the United States sixth, and Sweden seventh. These countries accounted for a very large proportion of the total trade. Even greater concentration took place in the years that followed, so that by 1929 Germany had only five important markets (the United Kingdom, the United States, Argentina, Switzerland and the Netherlands, ranked in that order). During recent years the United States, Switzerland and the Netherlands have purchased decreasing amounts of this German product, while Denmark and Sweden have returned to their former ranking positions. During 1937 the United Kingdom and Argentina were the leading purchasers of German plate glass.

British plate glass exports totaling 6,200 tons in 1920 had increased to 17,000 tons by 1926. They held up fairly well until 1932, when they were reported at 7,300 tons; the 1938 trade totaled 5,700 tons. In 1920 over 60 per cent of these exports were to British countries, while Japan, Argentina, Brazil and China were the leading foreign markets. A slightly larger percentage was exported to the colonies in 1929 as Denmark, the United States and the Netherlands were added to the list of other important outlets. Shipments to Empire markets have held up well during recent years, despite the decline in total British exports. During 1937 only 15 per cent of this trade was with foreign countries.

Czecho-Slovakian exports of plate glass, estimated at

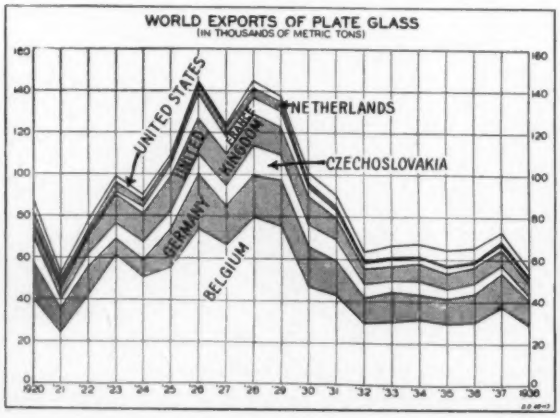
12,000 tons in 1920, remained below that level until 1928 when they totaled 14,200 tons. After that they declined almost continuously to the 1938 low of 2,500 tons. Austria was the leading foreign consumer of plate glass in 1920; France, Germany, Italy and Switzerland followed in that order. By 1929 the United Kingdom was importing such large quantities of this product that she outranked Austria, who dropped to second place; Hungary, China, Egypt and Germany were the other important outlets that year. The United Kingdom continued to hold first rank through 1937, but Austria declined to third position, being supplanted by Argentina. Czecho-Slovakian exports that year were heavy to Egypt, Poland and the United States also.

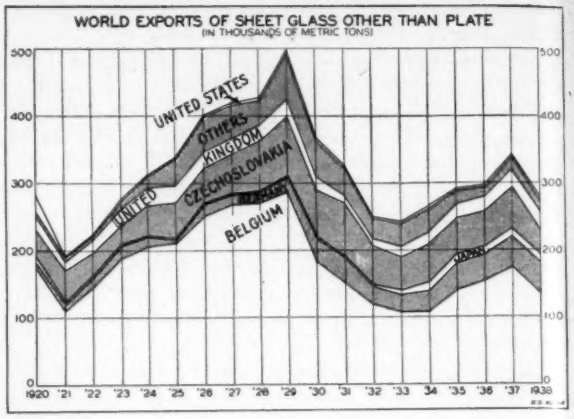
United States exports of plate glass amounted to 5,900 tons in 1920, but declined rapidly in the years that followed to a low point of 1,200 tons in 1926. After that, they picked up gradually to the 1935 total of 7,500 tons, then dropped off to 3,600 tons in 1938. Shipments during 1920 were heaviest to Japan, Canada, Cuba, Australia and Argentina in that order. In 1929 Canada took over half of the total exports, while Mexico and the Philippines were the only other areas that imported large quantities that year. Canada and Mexico have continued their leading roles as importers of this glass and, in recent years, Cuba has placed large orders in the United States.

Sheet Glass Other Than Plate

Although, for the purposes of this survey, all sheet glass other than plate has been combined, it may be assumed that this is primarily a window glass classification. During the period under review, Belgium was the leading supplier of this type of glass, Czecho-Slovakia ranked second, France third, Germany fourth, the United Kingdom fifth, and Japan sixth. The United States, Italy, Sweden and the Netherlands were not factors in this trade, with the exception of 1920 when the United States made sizable shipments to War markets.

Belgium's foreign sales of sheet glass, estimated at 174,700 tons during 1920, declined in the following year, but increased gradually in the subsequent period to a 286,700 ton peak in 1929. The next year they began a steady decline, reaching the low point of 106,800 tons in 1933. This trade recovered from 1934 to 1937, but dropped again in 1938. France and the United Kingdom were Belgium's leading sheet glass markets in 1920; the





Netherlands, Argentina, China, Australia and Turkey were the other important outlets in that year. During the period that followed, the Netherlands and the United States purchased increasing amounts of this glass, so that by 1929 they ranked first and second respectively among Belgium's foreign customers. Exports to France were at a much lower volume, but the British trade held third place; shipments were heavy to Canada, Argentina and China also. In 1937 the United Kingdom was Belgium's most important market again. During that year the Netherlands dropped to second position, and the United States to fourth, while Canada rose to third place; sizable exports were made also to Argentina, Brazil and British India.

Czecho-Slovakian exports of sheet glass totaled 40,400 tons in 1920 and maintained that general average until the 1927-1929 period when they increased to as high as 87,400 tons a year. This trade dropped off gradually in the years that followed, reaching the low point of 35,100 tons in 1938. During 1920 this trade was heaviest with Austria, Yugoslavia, Italy, Hungary, Germany and Rumania. The United States, Poland and the United Kingdom were added to this list of leading markets by 1929 as Austria, Italy and Rumania assumed lesser roles. During 1937 the United Kingdom was the leading importer of this glass from Czecho-Slovakia, Germany ranked second, and the United States, Canada, the Netherlands, Argentina and China followed in that order.

French exports of sheet glass during 1920 amounted to only 6,400 tons. Subsequently, they increased, reaching a record volume of 69,200 tons in 1929. They dropped off gradually during the depression, and were at a low point in 1938 with an estimated total of 15,300 tons. French colonies have accounted for a good portion of this export trade—particularly in recent years. Of the 1920 total, 14 per cent went to colonies, while a large part of the balance was shipped to Italy, Switzerland and Belgium. Subsequently, the colonies took a smaller percentage as gains were made in such markets as Belgium and Germany; in 1929 their participation had declined to 10 per cent. Recently, however, with the decrease in French exports to other foreign markets, the colonial trade has become extremely important to the sheet glass industry. In 1937 it represented 56 per cent of the total exports.

Germany reported a total export of 7,800 tons of sheet glass other than plate for 1920. During the three years

immediately following, this increased, then declined to 5,500 tons in 1925. From 1926 on, these exports attained higher levels, with the peak total of 46,500 tons recorded for 1938. The bulk of Germany's foreign sales of sheet glass during 1920 went to the Netherlands, Austria and France, in that order of importance. In the 1920-1929 period, the Netherlands continued as the leading market, Austria dropped to a much lower rank, and France went to fifth place. Meanwhile, the United States became Germany's second best customer, followed by the United Kingdom and Argentina. Recently, German exports to the United States have been small, but the Netherlands and the United Kingdom have continued as important markets. At the same time, China, Turkey, Brazil, Denmark and Uruguay have become important outlets for German sheet glass, while Argentina has continued her large purchases.

British exports of sheet glass totaled 19,500 tons in 1920. They declined in the following year, but from then on gained in volume, averaging about 25,000 tons annually until 1930. During the depression these exports were at a somewhat lower level, but increased in 1938 to 28,000 tons. Over 60 per cent of the United Kingdom's sheet glass exports went to British countries in 1920. This increased to 65 per cent in 1929 and to 90 per cent in 1937. Argentina and Denmark have been other consistently large buyers, and in the 1920-1929 period, sizable exports went to Brazil, France, Japan, China and the United States also.

Japan's export trade in sheet glass totaled 8,700 tons in 1920, but dropped to a much lower level for the 1921-1932 period. After that it rose to an average of 12,000 tons a year—the 1938 total being 11,500 tons. Far Eastern countries were Japan's leading sheet glass markets until recent years. In 1920 Kwantung Province, China, Australia, the Netherlands Indies and the Philippine Islands took the greater portion of these shipments. By 1929 British India was not only added to this list, but was the leading purchaser; Siam (Thailand) was ranked second that year. During the 1929-1937 period, Japanese sheet glass exporters obtained large orders from Canada, the Union of South Africa and Argentina; at the same time, they maintained their sales in the previously mentioned countries.

Glass Containers

Glass container exports were at their peak in 1920 when their volume was estimated at 338,000 tons. They held up rather well through the 1920-1929 period, but afterwards dropped to as low as 122,900 tons (1932). Since then, the trade has fluctuated between that low point and the 1937 volume of 221,800 tons; the 1938 figure was 182,400 tons. With the exception of 1920, France was the world's leading exporter of this item until 1930, when Germany assumed this position for a two-year period. Beginning in 1932, Japan dominated this trade. Czecho-Slovakia, the United States, the United Kingdom, the Netherlands and Sweden have been other important suppliers.

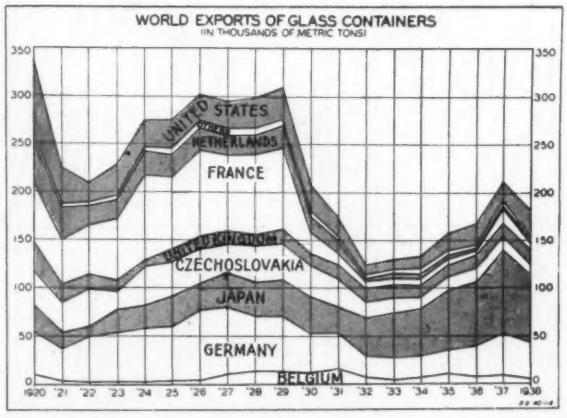
French exports of containers totaled 62,000 tons in 1920, dropped to 50,900 tons by 1922 and afterwards increased, rising as high as 85,300 tons in 1929. During the period that followed, they were at a much lower level, hitting the low point of 5,100 tons in 1936. This was not quite as sharp a decline as these statistics indicate, since exports of filled bottles, which were included in official statistics previous to 1930, were not computed in the years that followed. Approximately 20 per cent of France's total exports of containers were shipped to French colonies in 1920. The United Kingdom, Belgium, Spain, Switzerland and Italy were the other more important purchasers. As these exports declined, larger percentages of this trade became of a colonial nature. During 1929 they accounted for 40 per cent of all overseas shipments, the remainder being made up to a great extent by exports to Germany, Belgium, the United Kingdom, Switzerland and Spain. By 1937 over 90 per cent of this trade was with the colonies.

German shipments totaled 45,000 tons in 1920 and dropped to 35,000 tons in 1921. Subsequently, they varied between that and 73,000 tons until 1926. A decline, beginning in 1927, brought the level of this trade down to 21,600 tons by 1934. There has been some increase since; 1938's volume was estimated at 37,700 tons. The United Kingdom was Germany's leading container market during the 1920-1929 period. Denmark, France, the Netherlands, Norway and Switzerland were other important customers in 1920, but by 1929 this trade had shifted to Latin America, South Africa and British India, leaving only Switzerland and the Netherlands among the ranking markets. Exports were particularly heavy to Colombia, Cuba and Venezuela. After 1929 the British market became of decreasing importance, while the Latin American trade increased. In 1937 Venezuela was Germany's leading customer, followed by British India, Bolivia, the Union of South Africa, Belgium and Cuba.

Japan's container export trade was estimated at 27,500 tons in 1920. It dropped below that level until 1925, when it was estimated at 30,900 tons. During the 1926-1932 era it fluctuated between 27,000 and 40,000 tons, but after that period rapid strides were made to the 1937 peak of 87,200 tons. British India has been Japan's leading container market for many years. Australia ranked second in 1920, but declined to a less important position in the years that followed. China held third place through the 1920-1929 period, but the Philippine trade has held this rank in recent years. The United Kingdom, South Africa, Siam (Thailand) and the Straits Settlements complete the list of leading importers of Japanese containers.

Czecho-Slovakia's exports of containers totaled 35,400

(*Continued on page* 198)



CURRENT STATISTICAL POSITION OF GLASS

Activity in the glass industry declined during February following the usual seasonal pattern; decreased production, employment and payroll estimates testify to this fact. However, statistics indicate a considerable improvement over February of last year. Foreign trade returns were particularly encouraging with exports approaching $1,000,000 and imports dropping to little more than $200,000.

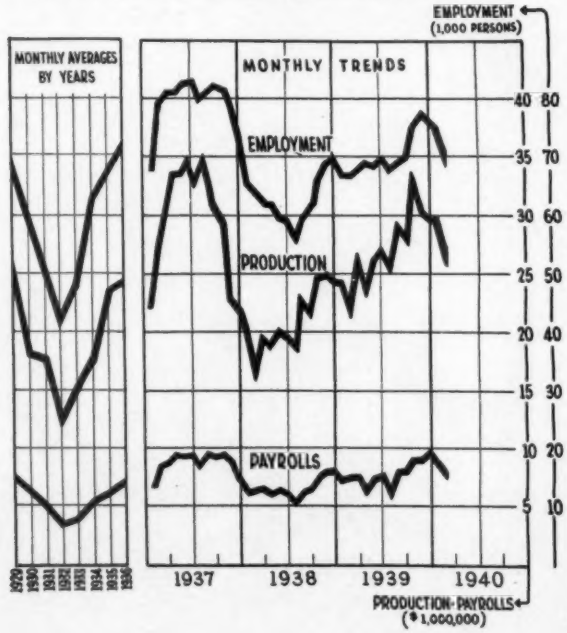
According to GLASS INDUSTRY's Production Index, February's output dropped 10 per cent below January to $27,000,000 but was 20 per cent greater than in February of last year. Almost all branches of the industry, with the exception of illuminating ware plants, experienced decreased activity. Output for the first two months of the year is estimated at $57,000,000—almost 20 per cent above last year's level.

Plate Glass production during February amounted to 13,172,212 square feet, according to the Plate Glass Manufacturers of America. While this represented a decline of 24 per cent from the previous month, it was an increase of 30 per cent over February of last year. Totals for the first two months indicate that 1940 plate glass activity is running about 36 per cent ahead of 1939 and within 3 per cent of 1936 (this industry's record year).

Window Glass output during February totaled 1,099,049 boxes, according to the Window Glass Manufacturers' Association. This was 22 per cent below January's rate of activity, but 36 per cent above the comparable month of 1939. During the first 2 months of this year, window glass production was reported at 2,512,000 boxes, which compares favorably with 1,752,000 boxes during last year's similar period and 1,263,000 boxes in 1937. This improved situation is even more significant when it is remembered that a number of plants did not operate during the first ten days of the month because of the deadlock in negotiations for new wage agreements.

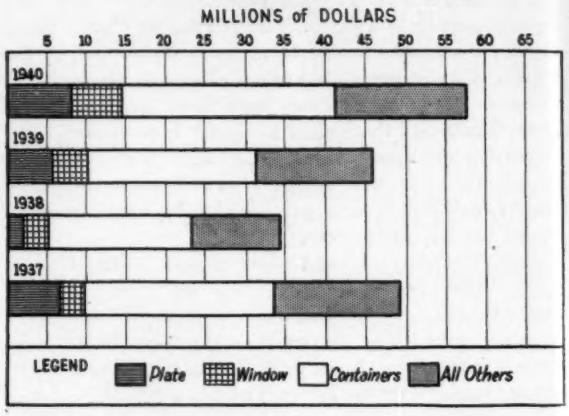
GI THE GLASS INDUSTRY'S INDEX

Monthly Trends Through February, 1940



GI THE GLASS INDUSTRY'S INDEX

Production for Two Months, January and February



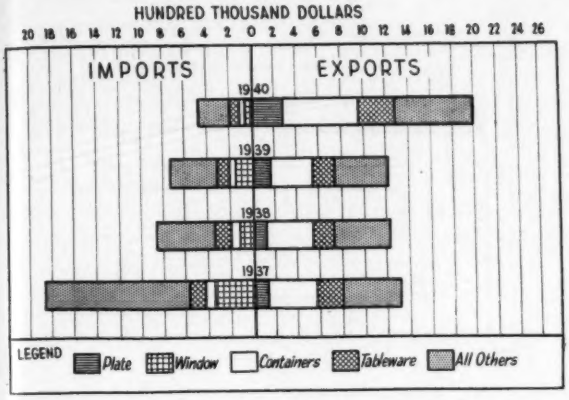
Glass Container production during February amounted to 4,122,667 gross according to the Glass Container Association. This was 3 per cent below January's level but was 22 per cent above February of 1939; in fact, it was the largest February output in the history of this industry. Totals for the first two months reveal that container plants were operating 20 per cent above 1939 levels and 6 per cent ahead of the comparable period of the record year 1937. Domestic shipments increased about 3 per cent over January to 3,830,729 gross, but were not large enough to alleviate the current high inventory position; stocks on hand increased to a new peak of 9,807,239 gross. It was reported that price cutting was practiced in some instances in an attempt to move some of this ware.

Miscellaneous Glass Products manufactured during February were valued at approximately $8,500,000 according to reliable estimates. This was a decrease of almost 10 per cent from the previous month but was 20 per cent greater than last February's total. Illuminating ware producers reported increases over January running up to 5 per cent; estimates show this output was about 10 per cent above last year's level. Tableware activity, while considerably above last February, fell off during the month under review. Output of technical, scientific and industrial wares continued strong.

Employment and Payrolls: Approximately 71,500 workers were employed in the glass industry during February according to preliminary estimates of the Bureau of Labor Statistics. This was about 2,500 less than January's total but was 5,000 more than in February 1939.

THE GLASS INDUSTRY'S INDEX

Foreign Trade for Two Months, January and February



Payrolls in the glass industry during February totalled about $8,000,000—$400,000 below January but 800,000 above February of last year. During the first two months of 1940 glass manufacturers paid out almost $16,500,000 in wages or over $2,000,000 more than in last year's comparable period.

Foreign Trade in glassware during February dropped 7 per cent below January's level to $1,175,000. Exports totalled $961,000 in February revealing a decline of 7 per cent from the previous month. This was traceable to a drop of 60 per cent in plate glass and 9 per cent in miscellaneous products. Gains were reported for other lines; tableware shipments increased 47 per cent, window glass 8 per cent, containers 3 per cent and illuminating ware 4 per cent.

Year to year comparisons of February export totals indicate an increase of 55 per cent over 1939 with window glass sales up 550 per cent, containers up 84 per cent, and illuminating ware up 58 per cent. During the first two months of 1940 exports were valued at $1,996,000 which compares favorably with $1,234,000 in 1939. All glass items shared in this increased trade.

Imports of glass and glass products during February dipped 9 per cent below January's total to $214,000—the lowest monthly volume in recent years. Declines from the previous month were noted in plate and window glass and containers but increases were reported in other lines. February's imports were 43 per cent below the same month last year.

Combined totals for January and February show that this year's import trade is running almost 40 per cent below last year's. Larger amounts of plate glass have been brought in but purchases of other foreign glass products have fallen off considerably. Imports of window glass were down 61 per cent, containers 49 per cent, illuminating ware 88 per cent and tableware 2 per cent.

RECENT EXPORT TRADE OPPORTUNITIES

Below is a list of recent inquiries received at the Specialties Division, Bureau of Foreign and Domestic Commerce. Those interested should write immediately to H. B. McCoy, chief of the division, or to any of the Bureau's District or Cooperative offices, specifying the reference numbers of any inquiries they wish to contact.

Reference Number	*Commodity*	*City and Country*	*Purchase or Agency*
6043	Glassware, table, plain and fancy	Johannesburg	Agency
6506	Glass containers	San Jose, Costa Rica	Agency
6535	Sheet and plate glass; obscured glass	Capetown	Agency
6543	Structural glass	Buenos Aires	Purchase
6580	Glass bulbs, flange tubes exhaust tubes and rods, for incandescent lamps	Calcutta, India	Purchase
6557	Household and hotel glassware	Quito, Ecuador	Purchase
6551	Glassware and bottles	Cairo, Egypt	Agency
6575	Glassware	Cairo, Egypt	Agency
6669	Bottles for beer; crown corks and caps	Brussels, Belgium	Purchase
6610	Bottles; ointment jars	Singapore	Purchase
6617	Cut-glass table service, glass salad bowls, and liquor sets	Rio de Janeiro	Agency
6607	Construction, flat, plate glass	Rio de Janeiro	Agency
6642	Window glass	Alexandria, Egypt	Both
6616	Glassware	Porto Alegre, Brazil	Agency
6622	Glassware	Capetown	Agency
6761	Glassware	Valparaiso, Chile	Agency
6682	Glassware, druggists', laboratory, and hospital	Cairo, Egypt	Agency

UNITED STATES FOREIGN TRADE IN GLASS
(Values in Thousands of Dollars)

	1940			*1939*		*Percentage Change*		
	February	*January*	*Two Months*	*February*	*Two Months*	*Feb.-Jan.*	*Feb.-Feb.*	*Two Months*
EXPORTS								
Plate	78	196	274	74	146	—60	+ 5	+ 88
Window	13	12	25	2	7	+ 8	+550	+257
Containers	346	337	683	188	387	+ 3	+ 84	+ 76
Tableware	185	126	311	114	218	+47	+ 62	+ 14
Illuminating Ware	52	50	102	33	70	+ 4	+ 58	+ 46
All Other	287	314	601	210	406	— 9	+ 37	+ 48
Total	961	1035	1996	621	1234	— 7	+ 55	+ 62
IMPORTS								
Plate	6	23	29	4	8	—74	+ 50	+262
Window	23	37	60	54	154	—38	— 57	— 61
Containers	11	15	26	29	51	—27	— 62	— 49
Tableware	48	47	95	63	97	+ 2	— 24	— 2
Illuminating Ware	6	4	10	43	81	+50	— 86	— 88
All Other	120	109	229	183	340	+10	— 34	— 33
Total	214	235	449	376	731	— 9	— 43	— 39

INVENTIONS AND INVENTORS

Summary of United States Patents of Interest to the Glass Industry Issued During February

Compositions:

As an opacifier for use in porcelain enamels, Glenn H. McIntyre, Monroe J. Bahnsen, and Benjamin J. Sweo of Ferro Enamel Corp., Cleveland, patented a pre-formed product having the general composition: $Sb_2O_5.TiO_2.2CaF_2.2.5CaO$. This is patent 2,189,148.

Furnaces:

George R. Rowe of Wethersfield, Conn. (Hartford-Empire) patented an improvement in forehearths, to overcome channeling and the delivery of glass varying in temperature, and therefore in working quality. This tendency is overcome by the means illustrated in Fig. 1, whereby two vertical refractory stirring members (34) placed near the side walls, and to the rear of the delivery point, are rotated in opposite directions. Their position with respect to the delivery point may be altered. (Pat. 2,189,271).

A feeder guide or die member for the outlet of a glass tank, such as those in forming the insulating material in the base of an incandescent electric lamp, was patented by Henry K. Richardson of Bloomfield, N. J. This patent 2,190,296 was assigned equally to Westinghouse Electric & Manufacturing Co., and to Baker & Co., Inc. of Newark, N. J. Mr. Richardson replaces the common glazed porcelain die with a refractory ring lined with a tubular platinum alloy shape. The principal objective of the several variants of the main idea is that of supplying an aperture of constant size so the amount of glass delivered will not vary excessively.

Feeding, Forming and Shaping:

Fig. 2 shows a novel glass delivery trough used in Albert F. Tremblay's newly patented apparatus for delivering and gathering a glass charge. (Patent 2,191,733, assigned to Kent-Owens Machine Co., of Toledo). The delivery trough floats or is fixed in the forebay, opening from the side of a glass furnace. The gathering device picks up its charge from this trough and then moves away in the manner indicated by the lower half of Fig. 2, without severing itself from the main glass body, until

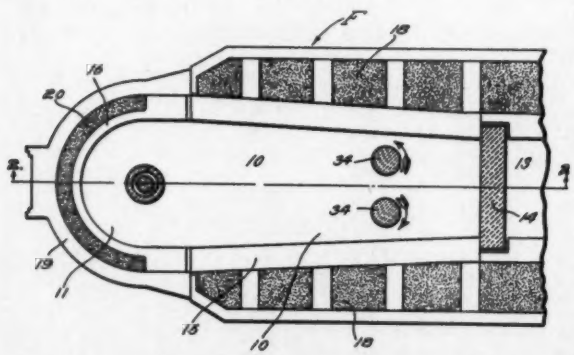


Fig. 1 Rowe: 2,189,271. Forehearth design with vertical stirrers (34) to improve glass circulation.

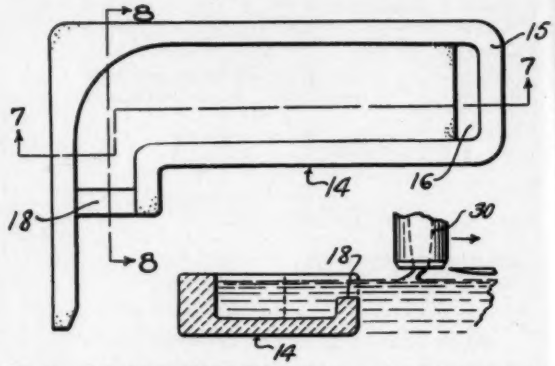


Fig. 2. Tremblay: 2,191,733. Delivery trough designed to prevent back-flow of cooler glass.

past the restricted opening caused by dam 18. Since this prevents flow into the trough over the dam, the glass within the trough is replenished by flow upward through the opening 16, shown in the upper portion of the figure. This prevents the back flow of chilled glass which may be less suitable for shaping.

A glassware forming machine patented by Frank O'Neill of Miami Beach, Fla., was assigned to Owens-Illinois Glass Co., (2,191,132). The patented features relate more particularly to the type of machine comprising blank and finishing mold tables arranged side by side and rotating continuousy about separate vertical axes, and in which the charges are gathered by suction blank molds which travel over the exposed surface of a pool of molten glass. All claims were directed to features of the blank mold unit, for which the O'Neill apparatus is said to provide a generally simplified and improved structure. The patent is illustrated by twenty drawings which cover twelve pages.

Thomas F. Pearson of Pontefract, England, was granted patents 2,190,042 and 2,191,237, which were assigned to Crown Cork & Seal Co. The first relates to a valve assembly and its application to a mold unit, as a means of insuring the application and cutting off of both vacuum and compressed air at the proper periods during the production of bottles, etc. The latter Pearson patent also concerns a glassware forming machine and provides for the oscillation in the path of the parison or blank mold of the funnel which guides the charge to the mold, and the baffle which closes the mold opening and serves also to support the base of the article to be blown.

Miscellaneous Processes:

Orie Shackelford of Fairmont, W. Va., obtained a patent 2,191,591 on an automatic stacker for positioning bottles as they enter a lehr. The stacker preferably constitutes a continuation of the lehr itself. As shown in Fig. 3, the bottles enter the V shaped stacker by the lead-in conveyor 71, and are moved either to the left or right by a series of deflectors which divide the single incoming stream of bottles into a number of lines. The arresting means holds the several botles on the "starting

line" until the last bottle to arrive has reached its place in line, whereupon all of the bottles are released at once to move into the lehr together. Each individual line of bottles is staggered with respect to the next line to avoid longitudinal drafts.

The stencil screen patented by Harry E. Playford and Franklin B. Holliger of Toledo (2,191,134 to Owens-Illinois) was designed to economize on screen cloth which may cost as much as ten dollars per square yard. As shown in Fig. 4, only section 14 is screen cloth, the larger area 12 preferably being a transparent membrane such as Celluloid.

Owens-Illinois was also assignee of patent 2,191,143 granted to Earl Hiatt and John J. Macken of Muncie. This patent is concerned with apparatus for handling glassware.

Two patents were concerned with glass-to-metal seals. In 2,189,970, Stanton Umbreit, assignor to Radio Corp. of America, proposed to modify the character of a nickel-iron-cobalt alloy by a carbonizing treatment, so as to improve the adherence to boro-silicate glass. Ernst Waldschmidt in patent 2,190,302 (assigned to Fides Gesellschaft für die Verwaltung und Verwertung von gewerblichen Schutzrechten mit beschränkter Haftung, Berlin) was concerned with a seal between a glass container and a hollow metal tube.

A glass cutting machine was patented by Geo. W. Burroughs of Ridgewood, N. Y. (2,190,641).

Robert A. Yuchtmann obtained one claim in his patent 2,191,245 for a glass working tool for transmitting a design to the base of stem glass ware.

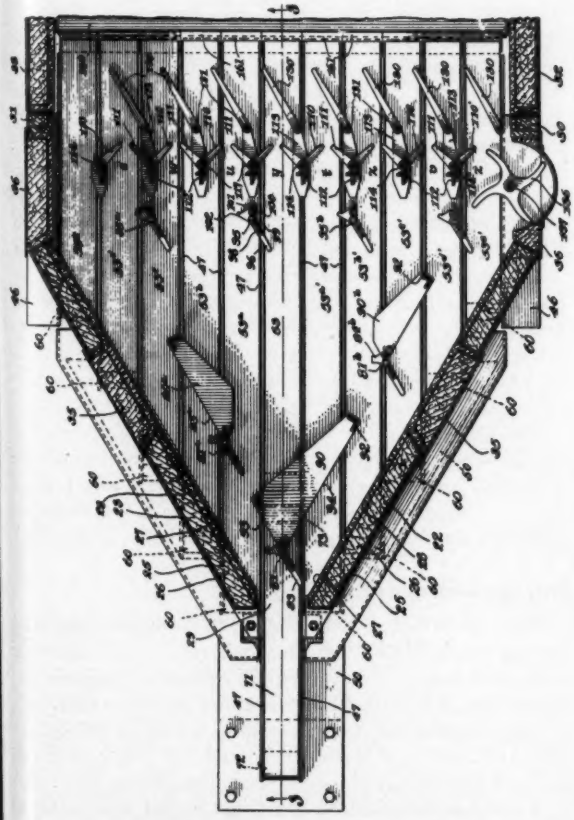


Fig. 3. Shackelford: 2,191,591. Lehr stacker.

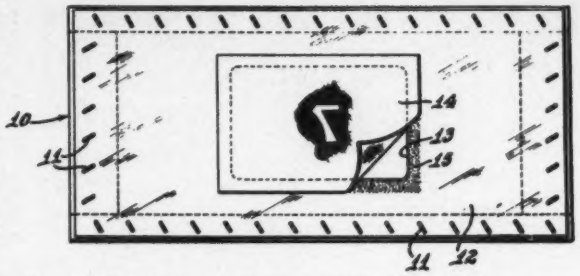


Fig. 4. Playford and Holliger: 2,191,134. Stencil screen utilizing minimum of expensive screen cloth (14), and providing transparent membrane (12).

In classifying grinding sand for reuse, James R. Jones of Kingsport, Tenn., concluded that the apparent loss of abrading power was due to the presence of metallic iron particles, which due to their greater weight, are classified with larger sand particles. His patent 2,191,962 issued Feb. 27, contains two claims, each applying to the removal of the iron particles, as by magnetic means, before classifying the sand.

Elmer H. Haux of Tarentum, Pa., assigned to Pittsburgh Plate Glass Co., his patent 2,191,658 for a method of preparing a cellular glass or slag construction block which can be readily nailed or sawed. Pulverized glass mixed with 1 to 2 per cent calcium carbonate as a gas forming agent, is heated gradually in a cylindrical machine from which the bubbled plastic product flows or is extruded as a sheet onto a conveyor.

Plates and Sheets:

In the field of plate and sheet glass, the small number of patents issued in February was entirely out of line with the unceasing activity usually indicated in this group. The two patents issued were 2,189,293 to Iwan Ostromislensky of New York (Carbide & Carbon Chemical Co.) and 2,191,367 to Wallace H. Carothers of Wilmington, Del. (E. I. duPont de Nemours & Co.). Both were concerned with plastic-joined laminated glass. The Ostromislensky patent which was in process of examination for slightly more than twelve years, covers the use of polystyrol as the adhesive. The Carrothers laminated

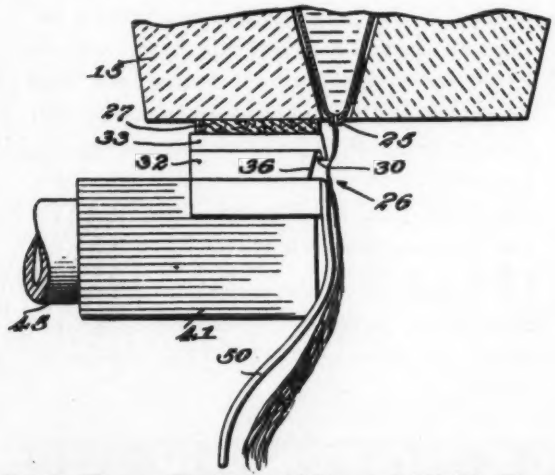


Fig. 5. Thomas, Fletcher and Atkinson: 2,189,822. Blown fibers are directed against a curved shield (50) to improve their matting qualities.

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sheet uses a synthetic linear condensation polymer capable of being drawn into fibers which exhibit orientation along the fiber axis when examined by X-ray.

Glass Blocks:

A group of three patents on apparatus and methods of making hollow glass blocks was issued to Henry H. Blau of Corning Glass Works. These patents (2,191,951 to 2,191, 953) were applied for in September-October, 1937. Each applies to the manufacture of blocks employing, as usual two preformed halves. Patent 2,191,951 discloses the value of, and covers by claims, a "dwell" period to be made use of just as the heated flanges of the two halves are brought together and before they have been pressed together sufficiently to complete the seal. The dwell allows gases to escape which otherwise may cause blowouts or weakening of the joint, since they will subsequently become hotter. Blau's patent 2,191,953 covers an apparatus in which the edges of the preformed halves of the blocks are heated at one station and pressed together at another station, to form the hollow block. The third patent in this group (2,191,952) is directed toward smoothing the bead which may be developed at the junction of the two halves of the hollow block. A method is disclosed whereby pressure is applied to all parts of the joint immediately after it has been sealed.

Glass Wool and Fiber:

Three patents concerning fiber glass manufacture, were granted in February and assigned to Owens-Corning Fiberglas Co. These were 2,188,927 to Games Slayter, 2,189,822 to John H. Thomas, Ed. Fletcher, and F. W. Atkinson, and 2,189,840 to A. L. Simison and Howard W. Collins, all being located at Newark, Ohio.

In this latest Slayter patent the characteristics of the glass stream to be blown are controlled by an electrically-heated conduit through which the stream is caused to flow. This heating zone may be composed of a pair of electrodes which together provide the flow channel for the stream of molten glass, and from one to the other of which an electric current flows throught the glass stream.

The patent to Thomas, Fletcher and Atkinson is also concerned with glass fiber blowing. The fibers are directed by air currents against a curved shield (shown as 50 in Fig. 5) immediately after formation. This is said to impart a waviness or inherent curl which increases their matting properties.

The Simison-Collins patent covers a method for applying binding materials to fiber matting. In one of the methods claimed, the fibers are blown vertically onto a conveyor which forms the matting, while a simultaneous continuously directed spray of binder is being applied.

New Products and Uses:

Percy E. Knudsen and Melvin E. Toussaint assigned to Pittsburgh Plate Glass Co., their patent 2,191,668 for a sheeting construction for buildings made up of shingle-like plates of glass held in place in a novel manner.

Sash construction was covered by patents 2,190,096 to Harry W. Cook of Malta, Ohio, and 2,190,720 to Clyde D. Lowry of Toledo (Libbey-Owens-Ford Glass Co.).

A seal for evacuated devices (light bulbs) was patented by Wm. J. Hitchock of New York City (2,188,298).

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CURRENT PRICES OF GLASS-MAKING MATERIALS

FURNISHED BY PRODUCERS, MANUFACTURERS AND DEALERS

Base Materials

		Carlots	Less Carlots
Barium carbonate ($BaCO_3$), Crude, (Witherite) 90%, 99% through 200 mesh	ton	45.00	51.00
Barium sulphate, in bags	ton	19.00	24.00
Barium sulphate, glassmaker's, carlots, bulk f. o. b. shipping point	ton	15.00-16.00	18.00
Borax ($Na_2B_4O_710H_2O$)	lb.	....	....
Granulated	In bags, lb.	.0215	.027 -.0295
Powdered	In bags, lb.	.024	.0295-.032
Boric acid (H_3BO_3) granulated	In bags, lb.	.048	.054 -.0565
Calcium phosphate ($Ca_3(PO_4)_2$)	lb.	.07	.07½
Cryolite (Na_3AlF_6) Natural Greenland (Kryolith)	lb.	.0865-.0875	.0925
Synthetic (Artificial)	lb.	No supplies available.	
Feldspar—			
20 mesh	ton	11.00-13.25	
40 mesh	ton	11.50-13.75	
Granular	ton	11.75-14.00	
Semi-granular	ton	11.00-13.25	
L. C. L., (Min. 2 tons) $3.00 per ton additional plus charge for bags			
Fluorspar (CaF_2) domestic, ground, 96-98% (max SiO_2, 2½%)			
Bulk, carloads, f. o. b. mines	ton	30.00-31.00	....
In bags	ton	31.60-32.60	42.00-45.00
Kryolith (see Cryolite)			
Lead Oxide (Pb_3O_4) (red lead) (N. Y.)	lb.	.0775	....
In 5 Ton lots	lb.	....	.0825
Less than 5 Tons	lb.	....	.0875
Lime—			
Hydrated ($Ca(OH)_2$) (in paper sacks)	ton	8.50	8.50
Burnt (CaO) ground, in bulk	ton	7.00	....
Burnt, ground, in paper sacks	ton	9.00	9.00
Burnt, ground, in 180 lb. drums	Per drum	1.60	1.70
Kiln Dried ($CaCO_3$) 10x30 mesh	ton	1.75	....
Kiln Dried ($CaCO_3$) 16x120 mesh	ton	1.75	....
Nepheline Syenite, f. o. b. shipping point	ton	12.00-14.00	....
Potassium carbonate—			
Calcined (K_2CO_3) 96-98%	lb.	.065	.0675
Hydrated 80-85%	lb.	.055	.0575
Salt cake, glassmakers (Na_2SO_4)	ton	18.00-20.00	25.00
Soda ash (Na_2CO_3) dense, 58%—			
Bulk	Flat Per 100 lb	.95	....
In barrels	Per 100 lb.	1.35	....
In bags	Per 100 lb.	1.10	....
Sodium nitrate ($NaNO_3$)—			
Refined (gran.) in bbls	Per 100 lb.	....	2.50-2.90
95% and 97%			
Bulk	Per 100 lb.	1.35	....
200 lb. bags		1.415	1.44
100 lb. bags		1.45	1.475

Special Materials

		Carlots	Less Carlots
Aluminum hydrate ($Al(OH)_3$)	lb.	.026-.029	.03½
Aluminum oxide (Al_2O_3)	lb.	.07	.09
Antimony oxide (Sb_2O_3)	lb.	.15	.15½-.16
Arsenic trioxide (As_2O_3) (dense white) 99%	lb.	.03	.03½
Barium nitrate ($Ba(NO_3)_2$)	lb.	....	Open price.
Pyrophyllite, (20% Al_2O_3)	ton	9.00	12.00
Sodium fluosilicate (Na_2SiF_6)	lb.	.05½-.06	.06¼-.06½
Tin Oxide (SnO_2) in bbls	lb.	....	.51
Titanium Oxide (ceramic grade)			
In bags	lb.	.12	.12¼-.12¾
In barrels	lb.	.12¼	.12½-.13
Zinc Oxide (ZnO)			
American process, Bags	lb.	.06¼	.06½
White Seal, 150 lb. bbls	lb.	.08¾	.09
Green Seal bags	lb.	.08	.08¼
Domestic White Seal bags	lb.	.08½	.08¾
Red Seal, bags	lb.	.07½	.07¾
Zircon			
Refined Granular (Milled .01-.02c higher)		.06½	.07-.08

Coloring Materials

		Carlots	Less Carlots
Barium selenite ($BaSeO_3$)	lb.	....	1.40-1.60
(Commercial, 25% Selenium)	lb.	....	.85
Cadmium sulphide (CdS)	lb.	....	1.00-1.05
Cerium hydrate—			
100 lb. drums and 600 lb. barrels	lb.	....	.60
Chrome Oxide Green, 400 lb. bbls:	lb.	....	.22-.25
Chromite (99% through 200 mesh)	ton	40.00	44.50
Chromite ore (air floated)	ton	55.00	58.00-73.00
Cobalt oxide (Co_2O_3)			
In bbls	350 lbs. or more, lb.	....	1.84
	Less than 350 lbs., lb.	....	1.94
Copper oxide—			
Red (Cu_2O)	lb.	....	.165
Black (CuO)	lb.	....	.18-.19
Black prepared	lb.	....	.22
Iron Oxide—			
Red (Fe_2O_3)	lb.	....	.0425-.09
Black (Fe_3O_4)	lb.	.04½	.09
Iron Chromate	lb.	....	.035-.05
Lead Chromate ($PbCrO_4$) in bbls	lb.	....	.135
Manganese, Black Oxide			
In Paper bags	ton	62.50	65.50
In Burlap bags	ton	64.25	67.25
In Casks	ton	66.50	69.50
Neodymium oxalate, 50 lb. drums	lb.	....	3.50
Nickel oxide (Ni_2O_3), black	lb.	....	.35-.40
Nickel monoxide (NiO), green	lb.	....	.35-.37
Potassium bichromate ($K_2Cr_2O_7$)—			
Crystals and Granular	lb.	.08¾	.09-.09¼
Powdered	lb.	....	.09¼-.09¾
Potassium Chromate (K_2CrO_4) 100 lb. kegs	lb.	....	.27
Powder blue	lb.	....	.19-.24
Rare earth hydrate—			
100 lb. drums	lb.	....	.35
325 lb. barrels	lb.	....	.30
Selenium (Se) In 100 lb. lots	lb.	....	1.75
In lesser quantities	lb.	....	1.85
Sodium bichromate ($Na_2Cr_2O_7$)	lb.	.06¾	.07-.07¼
Sodium chromate (Na_2CrO_4) Anhydrous	lb.	.06¼	.06¾-.06⅞
Sodium selenite (Na_2SeO_3)	lb.	....	1.50-1.65.
Sodium uranate (Na_2UO_4) Orange	lb.	....	1.75-1.80
Yellow	lb.	....	1.75-1.80
Sulphur (S)—			
Flowers, in bbls	Per 100 lb.	3.35	3.70-4.10
Flowers, in bags	Per 100 lb.	3.00	3.35-3.75
Flour, heavy, in 250 lb. bbls	Per 100 lb.	2.90	3.25-3.65
Uranium oxide (UO_3) (black, 96% U_3O_8) 100 lb. lots. Black	lb.	....	2.65-2.75
Yellow orange	lb.	....	1.75-1.80

Polishing Materials

		Carlots	Less Carlots
Emery, Turkish	lb.	.063	.07
Pumice Stone,			
American Ground Italian FFF, FF, F	lb.	....	.03
0, 0½, ½, 1.	lb.	....	.04
Putty Powder	lb.	Open price.	
Rotten Stone, (Domestic)	lb.	....	.03½
Rouge, Red	lb.	....	.16
Black	lb.	....	.18

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Sodium Uranate · Sodium Selenite · Selenium · Sodium Silico Fluoride · Zinc Oxide

"CERAMIC" COLORS

CERAMIC COLOR & CHEMICAL MFG. CO.
NEW BRIGHTON, PENNSYLVANIA

(*Continued from page* 189)

tons in 1920. At that time, Italy, Poland, France, Hungary, the United Kingdom and Switzerland were the leading countries of destination for these products. This trade declined gradually during the next three years to 18,200 tons in 1923, but picked up in 1924, and averaged between 30,000 and 40,000 tons until 1931. British South Africa had become the leading market during this period and was followed closely by the United Kingdom, Austria, Switzerland and the Netherlands. Other important outlets at this time were Colombia, Italy, and Denmark. After 1930 these exports dipped sharply, reaching their lowest point in 1938 with a total of 9,800 tons. The bulk of these shipments in recent years were to Italy, the Netherlands, Norway and Belgium.

Container exports from the United States were highest in 1920 when this trade approximated 80,000 tons. As the other glass-supplying nations re-entered their pre-War markets, this volume dropped sharply, falling as low as 19,800 tons in 1922. It picked up a bit in the period that followed, running between 27,000 tons and 33,000 tons until 1931. During the depression years these shipments ran as low as 10,000 tons but are now back to 1930 levels. Cuba, the United Kingdom, Canada and Mexico were the leading markets during 1920. By 1929 Canada was in first place, followed by Cuba, the United Kingdom, Mexico and Argentina, in that order. Recently, Cuba has regained her leading position, sending Canada to second place. Other currently important markets are Colombia, Mexico, the Union of South Africa, Venezuela and Panama.

The United Kingdom's container export trade amounted to 30,000 tons in 1920, but dropped to 18,200 tons in 1921 and 15,000 tons in 1922. In subsequent years it fluctuated between 11,700 tons and 16,500 tons. The colonial markets are of major importance to British exporters of these articles. Over 70 per cent of the total overseas sales went to British countries in 1920, as compared to 68 per cent in 1929 and over 80 per cent in 1937. During 1920 the remainder of this trade was fairly well concentrated in Cuba, Turkey, Brazil, Belgium, the Philippines and the United States. However, soon after that date, British exports to foreign countries were quite scattered.

Container exports from the Netherlands totaled 42,700 tons in 1920 but declined almost continuously during the years that followed to 2,700 tons in 1932. They have not recovered to any noticeable extent. The United Kingdom, Belgium and Portugal were the important markets in 1920. In recent years, Belgium, Venezuela and the Union of South Africa have imported some of this ware; the United Kingdom has also continued her purchases of containers from the Netherlands, but on a much smaller scale.

Sweden has exported much smaller quantities of containers than the other major suppliers. This trade has averaged 4,500 tons, shipments having been heaviest to the United Kingdom and Norway. In 1937 sizable exports to the Union of South Africa and British India also were reported.

Pressed and Blown Glassware

The other group of glass products which move in large volumes to world markets includes such items as prisms, lamp chimneys, globes and shades, and a large variety of household glassware. For the purposes of this review, all articles of this nature have been combined under the general heading of pressed and blown glassware.

World exports of these items were estimated at 149,000 tons in 1920. During the next two years they declined to 119,700 tons, but increased steadily after that to 166,700 tons in 1929. Decreases occurred again during the depression, with the volume dropping as low as 78,000 tons in 1932. Recently they have been at a higher level, with 1938 activity estimated at 93,800 tons. Czecho-Slovakia was the leading exporter of pressed and blown glassware during the 1920-1938 period, Germany was next in importance, followed by Belgium, the United States, France, the Netherlands, the United Kingdom, Japan, Italy and Sweden, in that order.

Czecho-Slovakian exports of pressed and blown articles averaged 41,000 metric tons from 1920 until 1924. They were higher during the next 7 years, reaching 59,600 tons in 1927 and dropping to 50,300 tons by the end of this period. Since then they have ranged between 20,200 tons (1932) and 36,800 tons (1935); the 1938 total was 25,700 tons. While Austria, the United Kingdom, Italy, France, Hungary and Yugoslavia were the leading markets for this ware from 1920 until 1930, sizable shipments were made to a wide range of countries. After 1929 these exports became more concentrated, so that by 1937 the United Kingdom, France, the United States and Switzerland were purchasing the greater portion of these products.

German exports of this ware totaled 37,300 tons in 1920 and maintained about that average until 1932. This trade has fluctuated between 25,000 and 30,000 tons during recent years, the 1938 estimate being 28,700 tons. France was Germany's leading glassware market in 1920; Italy, the Netherlands, the United Kingdom and Austria followed in order of importance. However, by 1929 the United Kingdom had become the leading purchaser of these articles—a position which she held through 1937. During this same period the Netherlands has ranked second, Switzerland third and Belgium, Denmark, and France have alternated the other leading rankings.

Belgian foreign sales of pressed and blown glassware totaled 23,100 tons in 1920, dipped to 17,200 tons by 1922, then varied between 21,400 tons and 29,400 tons until 1932. Since then they have averaged about 14,000 tons, although the 1938 trade dropped to 12,500 tons. Consistently, the United Kingdom and France have been leading markets for Belgium glassware. During the 1920-1929 period large orders were also placed in Italy, Egypt, Switzerland, the Netherlands and Argentina. In recent years Canada and the United States have become important entities in this trade.

United States exports of pressed and blown glassware have not approached the 1920 figure of 26,000 tons since that year, but they have been large enough to class this country among the leading world suppliers. From 1921 to 1929 they ranged between 9,200 tons and 13,400 tons, but declined to 2,600 tons by 1933. During recent years they have picked up considerably, with 1938's trade estimated at 7,800 tons. During 1920 this trade was divided

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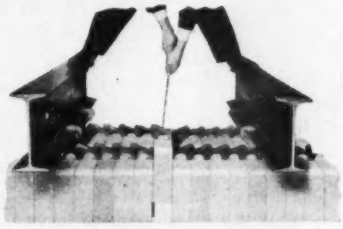

The Interlocking Suspended Arch

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Arches

For bringing the products of combustion closer to the melt and saving fuel in glass manufacturing, the Interlocking Suspended Arch is unexcelled. The troubles experienced with tie rods for taking up contraction or letting out for expansion when cooling or heating the tank is entirely eliminated by this unique crown construction. This Interlocking Suspended Type of Arch can be used as an Adjustable Shadow Wall for all tanks, especially sheet and plate glass tanks, with excellent refining end temperature control.

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Complete-muffle, semi-muffle, or open fired variety. Electric Heat can also be used. These lehrs will successfully anneal any type of glass.

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Either Fuel Fired or Electric Fired designs, or combinations of the two; afford remarkable fuel economy together with excellent atmosphere firing control.

More than thirty installations of the new Simplex Ready Heat Unit Lehrs have already been made in the glass industry.

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Completely muffled Dryers for one or more color decorations are available.

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Simplex designed Batch Plants minimize the necessary labor element and give more accurate weighings and mixings. Continuous Belt Conveyor Types and Mono-Rail Hopper designs are available.

Power shovel unloading equipment and hopper vacuum unloading equipment are also supplied.

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Batch Plant, Hart Glass Division, Armstrong Cork Co., Dunkirk, Ind.

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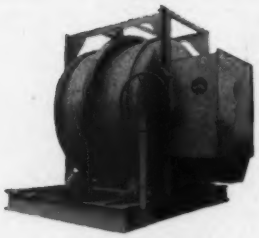
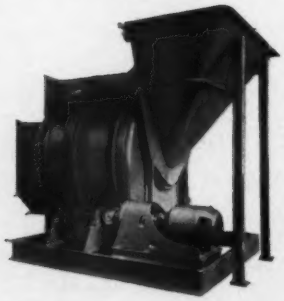
Typical Brick and Steel Factory Building, designed and erected by Frazier-Simplex, Inc.

This Mixing Action





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GLASS BATCH

MIXERS

WORLD TRADE IN GLASS

(*Continued from page* 190)

rather evenly among a number of markets, of which Canada, the United Kingdom, Cuba and Mexico were particularly outstanding. By 1929 it was more concentrated in these markets with the addition of Australia. Recently, Canada has taken almost half of the total exports of this ware, and a good share of the remainder has been shipped to Cuba and the United Kingdom.

France's export trade in pressed and blown glassware fluctuated between 6,200 tons (1922) and 12,800 tons (1926) during the 1920-1929 period. They dropped sharply to 1,500 tons in 1930, but have since increased to the 1938 estimate of 5,800 tons. The colonial trade in this ware has been particularly heavy, equalling 25 per cent of the total in 1920, 40 per cent in 1929, and 80 per cent in 1937. Belgium was the leading foreign market for this ware during 1920 and 1929, and ranked fourth in 1937. The United Kingdom, Switzerland, Italy and Germany have also proven valuable customers; the United States ranked third among these outlets in 1929 and has recently risen to first place.

Foreign shipments of pressed and blown ware from the Netherlands did not exceed 5,000 tons during the period under review, and in 1938 they were reported at only 2,800 tons. About half of these articles went to Dutch colonies in 1920; most of the balance being taken by the United Kingdom, Belgium and Italy. France and Germany became important factors around 1929, as this trade increased and colonial markets became insignificant. With the recent declines in volume, colonial markets have become important entities once again, taking almost 30 per cent of the total in 1937. Some large orders were placed in Switzerland and the United States that year which ranks them with the other important foreign purchasers.

The United Kingdom's overseas trade in pressed and blown glassware totaled 2,000 tons in 1920, and varied between 1,300 tons (1922) and 4,200 tons (1932) in the years that followed. During 1938 this trade was estimated at 2,300 tons. British countries accounted for 70 per cent of these exports in 1920 and about 80 per cent in 1929 and 1937. The United States, Argentina and France have been the other important outlets.

Japan's exports of pressed and blown glassware have been largest during recent years. During 1932 this trade ran as low as 300 tons, then increased gradually to 1937's record of 7,900 tons. British India, Australia, the Netherlands Indies, the Philippine Islands and the Straits Settlements have been the largest importers of Japanese ware, but the United States ranked third in this trade in 1937.

Italy and Sweden conclude the list of major exporters of pressed and blown glassware. Italian trade in these items totaled 1,900 tons in 1920, 500 tons in 1922, 800 tons in 1927, and 2,500 tons in 1938. France, the United States, the United Kingdom and British Africa have been the important markets, although in recent years Italian colonies have taken up to 70 per cent of these shipments. Swedish exports have been considerably smaller, running from 1,600 tons in 1920 to 200 tons in 1932 and 400 tons in 1937. Scandinavian countries, the United Kingdom, Australia and the United States have been the leading importers of this ware.

NEW USES FOR GLASS

(*Continued from page* 185)

the exteriors and interiors of buildings and bring light while they stop the passage of heat and noise. The inclusion of fiber glass in woven sheets in these blocks, or as the "sandwich" material between window panes, further increases the utility of glass in diffusing light and controlling temperature. Decorative panels, molded to sculptured designs and sandblasted to artistic textures, present architects with additional means for the adornment of buildings.

The impetus given to research on optical glass by the World War crisis has had continued and far-reaching effects. For example, the scientific treatment of strain and annealing not only enables technologists to do more perfect annealing where that was required, but also encouraged them to attempt the improvement of glass for certain purposes by disannealing, pre-straining, or "toughening." This rather old technique, now handled with understanding, has produced a new variety of safety glass, strong non-splintering goggles, and a type of cooking utensils that can be used directly exposed to flame.

Reflecting mirrors for telescopes are not new, but the bold and successful attempts to make them of heroic size, culminating in the giant mirror now almost ready at Mt. Palomar, required the accumulated knowledge possessed only in recent years.

The "dark glasses" of a former generation are succeeded by eye-protection goggles of known absorption characteristics. Workers with the electric arc or the acetylene flame are given comfort and safety as the result of applied scientific information. Thus advanced technology is being translated into new kinds and degrees of utility.

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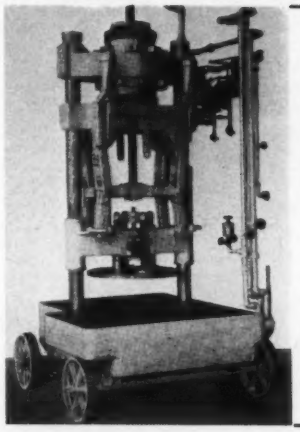

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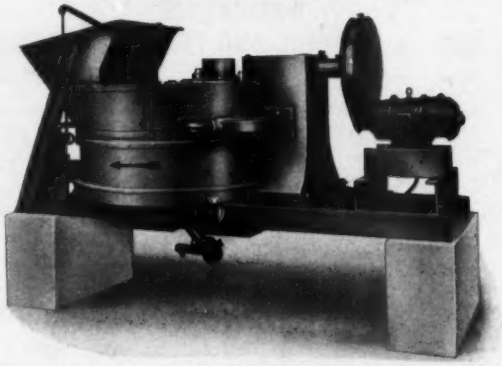

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PROGRESS IN GLASS MELTING

(*Continued from page* 170)

One of the important developments in furnace practice during the past two decades has been the application of scientific principles to the study of furnace operation and its corollary problem of combustion. The last word in furnace design and construction undoubtedly has not yet been spoken, but it is quite certain that future developments will be guided by a mass of scientific data which was not available 20 years ago. The study of convection currents in the furnace and the perfection of new methods for batch preparation and charging should have a definite effect on future glass furnace design and practice.

L. O. F. SHREVEPORT PLANT IN TORNADO

Considerable damage to the Libbey, Owens Ford Glass Co.'s plant at Shreveport, La., was inflicted by a tornado which struck with unprecedented violence on March 13. Wind velocity was higher than the Weather Bureau's instruments could record. Roofs were stripped off buildings and thousands of panes of windows were smashed. All machinery in the factory was at a standstill and could not be put back into production for practically a week. No damage was done to this equipment, however, nor to the lehrs and furnaces.

The greatest damage was done to the warehoused stocks. Glass, both packed and unpacked, received a thorough drenching, and the cased glass had to be opened, washed and re-packed. Damage was estimated to be in the neighborhood of $100,000 with an additional $75,000 for use and occupancy.

NEW CANADIAN BRAID PLANT

The International Braid Company of Canada is planning to erect a new plant at Ste. Rose, Quebec, for the manufacture of woven and braided glass products. This will be Canada's first factory for these products. The new building 80 by 380 feet, will cost $65,000 and will employ sixty persons.

B & L INDICTED WITH CARL ZEISS

The Bausch & Lomb Optical Co., Rochester, N. Y., has been indicted with Carl Zeiss of Jena, Germany, and the latter's New York subsidiary, Carl Zeiss, Inc., by a Federal Grand Jury, alleging monopoly of world trade in military optical instruments in violation of the Sherman Act and the Wilson Tariff Act. Individual defendants named included M. H. Eisenhart, president, Carl L. Bausch and Theodore Drescher, vice-presidents of Bausch & Lomb.

The defendants are accused of having entered into a secret agreement in 1921 to divide the world market in military optical goods, Bausch & Lomb taking the United States and Carl Zeiss the rest of the world. Since that year, Bausch & Lomb has refused to sell military optical instruments to foreign governments or to American shipyards building battleships on foreign order, unless Carl Zeiss of Jena consented to the sale and to the price. Carl Zeiss, the indictment further alleges, has refused in similar manner to sell American orders.

The charges, if sustained, constitute misdemeanors, punishable upon conviction with one year in prison and a fine of $5000.

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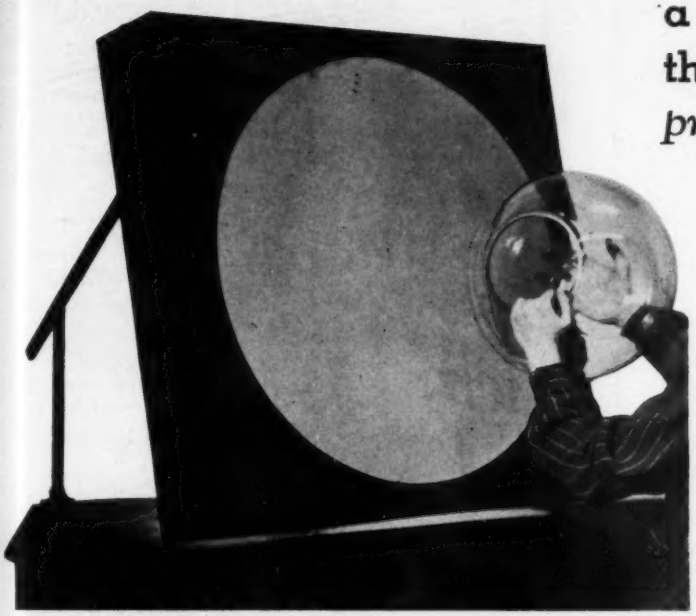
a development within the period of *20 years of progress in glass manufacturing.*



Largest Polaroid Strain Detector ever produced for use with Standard Strain Testing Spectacle. Approximately 30 inch aperture.

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This, the largest unit ever made, is of the *spectacle type* strain detector now in use by prominent organizations in the glass manufacturing field. The spectacle type strain detector, with polarizing spectacle mounted in unit with sensitive tint-plate of 565 millimicrons shows strains sharply defined in color. It is recognized as the most efficient method of strain detection available.

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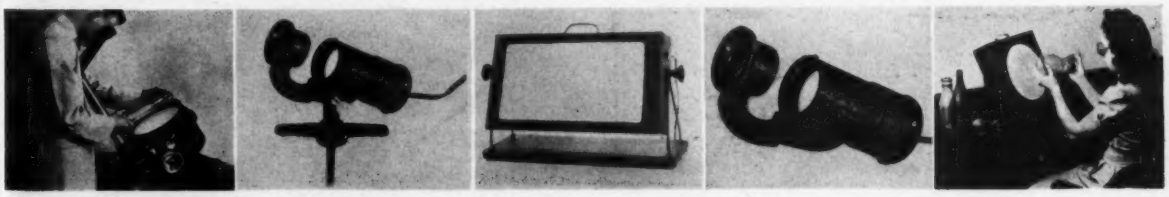

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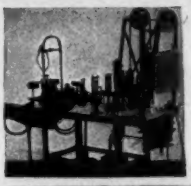

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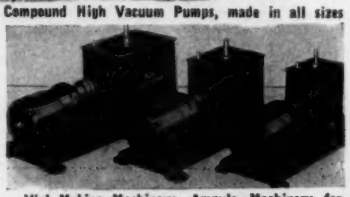

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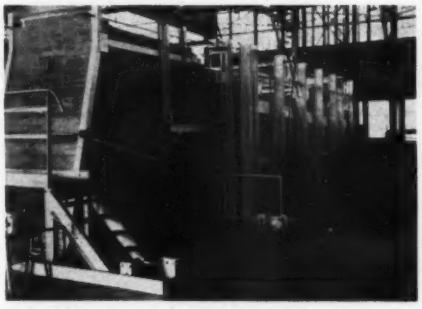

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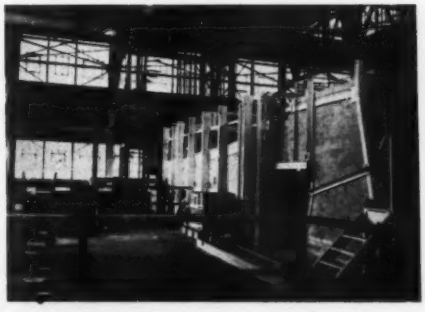

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